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VISUAL PERCEPTION APPROACHED BY THE METHOD OF STABILIZED IMAGES[1]

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THE PRESENT PAPER REPORTS some preliminary experiments on the Ditchburn-Riggs effect which is obtained with stabilized images. Our results are such as to show that the original discovery, made independently by Ditchburn and Riggs and their collaborators about 1952, has opened a new and valuable avenue of approach to the analysis of visual perception.

In normal visual fixation, the image that falls on the retina is never really stable; "physiological nystagmus," the continuous tremor of the normal eye at rest, causes a slight but constant variation in the rods and cones that are excited. It is now known that the variation plays a vital role in perception, for it was shown by Ditchburn and Ginsborg (1952) and Riggs, Ratliff, Cornsweet and Cornsweet (1953) that stabilizing the image (experimentally eliminating variability of retinal excitation) leads rapidly to the disappearance of the visual object, followed by intermittent reappearance.

In their experiments, the target was projected on a screen after being reflected from a small mirror attached to a contact lens worn by the observer. Thus each slight involuntary movement of the "fixated" eye would produce a movement of the target. By having the subject observe through a complex optical system, it was possible to make the two movements correspond exactly: the angular extent and direction of the eye movement were matched by the movement of the target, cancelling out the normal tremor of the eye and producing a stabilized retinal image. In these conditions the line of demarcation between the two halves of a 1 degree field, separately lighted so as to give intensity ratios of up to 3:1, disappears intermittently for 2 to 3 sec., at intervals of about 1 min. (Ditchburn & Ginsborg, 1952). Similarly, within a few seconds of stabilized viewing, a thin black line crossing a bright 1 degree field fades out; coarser lines are seen for longer periods, but still intermittently, the length of time the line remains visible being a direct function of its thickness (Riggs *et al.*, 1953).

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Later papers using this technique dealt with other aspects of the phenomenon, still with simple targets. Experimentally controlled movement of the image on the retina, as might be expected, restores the object to view, as does intermittent instead of continuous illumination (Cornsweet, 1956; Ditchburn & Fender, 1955; Ditchburn, Fender & Mayne, 1959; Krauskopf, 1956). Krauskopf also showed that narrow bars need a higher intensity (higher contrast ratio) than broad bars to be seen 50 per cent of the time; Fender (1956) and Clowes (1959), using coloured targets, showed that stabilization affects discrimination of hue as well as saturation and brightness.

Achieving stabilization by reflecting the image off the contact lens, however, has some limitations. The field that can be used is small, mainly because torsional movement is not controlled. The next step in the development of method was to attach the complete optical system to the eyeball itself (Ditchburn & Pritchard, 1956; MacKay, 1957; Yarbus, 1957). Since the optical system produces an apparently distant target, which is viewed with a relaxed eye, gross fluctuations of accommodation due to muscular fatigue could be ruled out as an explanation of fading. More important, larger and more complex figures could be used.

Ditchburn and Pritchard (1956) used interference fringes produced by a small calcite crystal between two polaroid sheets, and fastened by a stalk to a contact lens, to get a concentric ring pattern which covered a wide field and was in focus for a fully relaxed normal eye. With this method, it was found that the visual object is present for a very small fraction of the viewing time. Moreover, several observations of great interest were made (Pritchard, 1958; Pritchard & Vowles, 1960). It was found, in brief, that stimulation of other senses could affect the amount of time that the target was seen, and that when the subject's attention was directed to a particular part of the target, this part would usually remain in view longer. Also, it was shown that parts of interference fringes might appear and disappear independently of each other. It is these results which lead directly to the experiments which we now report.

Method

In the present investigation the method used to compensate for retinal-image motion produced by the involuntary eye movements is that described by Pritchard (1960). It consists, essentially, of a collimator device (i.e., one producing parallel rays of light), carried on a contact lens, as illustrated in Figure 1. The target to be viewed is maintained in the focal plane of a high-power glass lens and illuminated by a miniature surgical bulb attached to a diffusing screen. It is seen against a circular patch of light subtending 5 degrees, while the rest of the diffuser is blackened to shield the eye from stray light. The assembly of lens, target, and light source is mounted by a ball-socket joint to a stalk carried on a contact lens, corrected

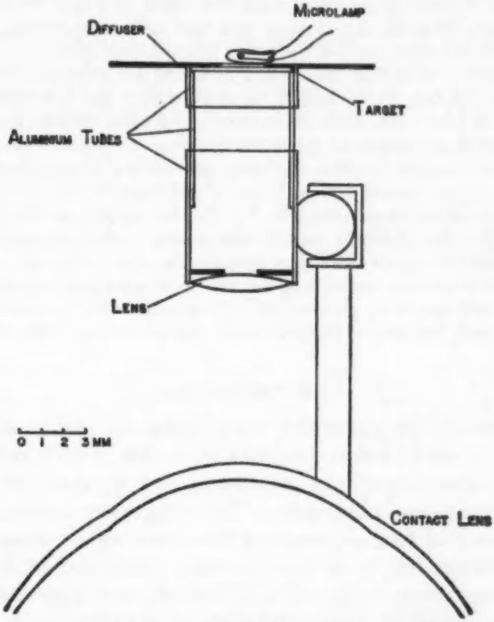


Figure 1. The apparatus used to produce stabilized images.

for the subject's visual defects, if any. The lens is tight fitting and thus follows small eye movements accurately (Ratliff & Riggs, 1950; Riggs, Armington, & Ratliff, 1954). The target is easily changed by unscrewing the top of the collimator assembly and replacing one small circular target by another. When the top is screwed down again, the new target is immediately secured in the focal plane of the high-power lens and no additional focusing is necessary.

The targets are produced by photographing India ink drawings on white cards, or drawings in white ink on black cards. Then, 5 mm. discs of the negative are viewed by the subject through the collimating lens and consequently are seen as if located at infinity. They are in focus, therefore, for the normal relaxed eye.

In the present study all the targets were presented within a central 2 degree field, in view of the earlier finding (Pritchard, 1958) of a marked difference between perception within this central region and more peripheral regions. All observations were monocular, the other eye being occluded. The luminance of the brightest parts of the target was maintained at approximately 25 millilamberts, with the experiment room in darkness during the viewing period.

The subject lay on a couch with his head supported, in a partly sound-proofed room or, in some of the observations, in an ordinary room at times when irregular auditory stimuli were at a minimum (cf. Pritchard & Vowles, 1960). The target was then put in position by the experimenter, and a continuous recording was made of the

subject's report. Control observations were also made, in which the subject viewed the same targets through the contact lens and collimator system, but without attaching one to the other, so that the image was not stabilized.

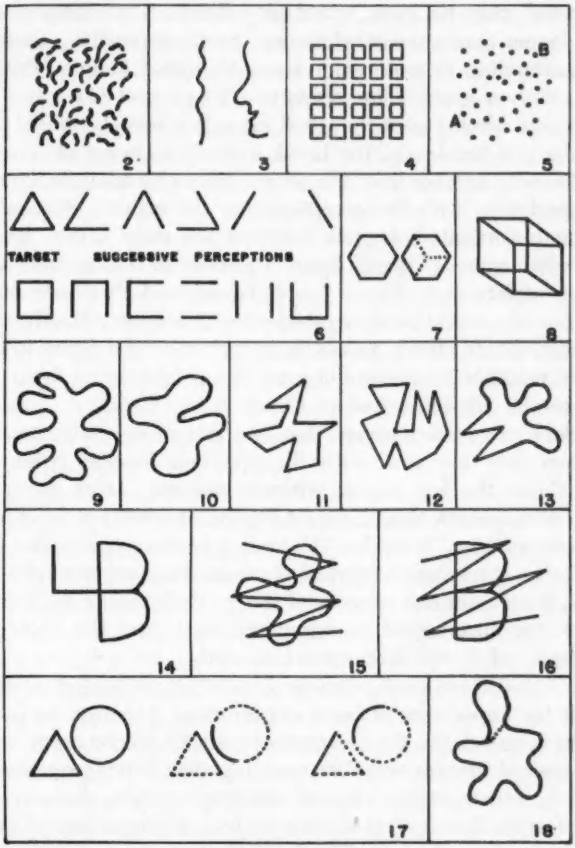
It is important to note that the subject must first be habituated to the viewing conditions, and for this reason reports obtained during the first three sessions, of approximately an hour each, were not recorded. For some subjects it is desirable at first to use a local anaesthetic to minimize sensations from the contact lens, which tend to produce frequent blinking and jerky movements of the eyeball, causing a slight slipping of the contact lens and loss of stabilization. But further, the visual phenomena themselves are so striking at first that the subject inevitably tries to look at the object that has suddenly vanished or equally suddenly popped into vision after having vanished, again destroying stabilization. Only when he has adapted to the phenomena themselves, enough to be able to observe passively, does he begin to obtain the full range of phenomena. When adaptation was achieved, in the present experiment, the subject observed and reported on some fifty different visual objects.

The Phenomena

The phenomena of perception with stabilized images and complex targets seem at first to have a bewildering variety, mostly without precedent in the subject's previous experience, but signs of order begin to appear with continued observation. The phenomena described here are from the reports of four experienced observers; unless otherwise stated, each phenomenon has been independently confirmed at least once, a second observer simply being asked to look at a new figure without being told what the preceding observer had found of interest in it.

When the figure is first presented, it remains intact for a length of time which depends on its complexity. With a single line as target, the line fades and disappears, leaving the more dimly illuminated field only. Eventually this disappears also, replaced by a "rich" or intense black patch. Subsequently it regenerates. A more complex target may behave similarly or it may instead lose one or more of its parts, in ways that will be described.

The time of the first disappearance varies, perhaps because of different levels of attention in the observer or because of variations in the level of unfamiliar auditory stimulation (Pritchard & Vowles, 1960), but disappearance is quicker with simpler figures. Also, it has been possible to determine that a simpler figure such as a line is visible for about 10 per cent of viewing time, while a more complex figure such as an unconnected set of curlicues or a facial profile (Figures 2, 3) retains at least one of its parts for as much as 80 per cent of the time. Such a comparison can be made directly by presenting two figures simultaneously (e.g. Figure 3); or the comparison may be quantified with repeated separate presentations, during which the observer presses a key whenever the figure is visible (Kader, 1960).



FIGURES 2–18. Examples of visual stimuli used (Figures 6, 7, 17 & 18 also show successive perceptions).

The greater time during which a more complex figure is present cannot be explained by assuming a random fluctuation of threshold in the different parts of the field. One might conclude, on such an assumption, that one or other part of the more complex figure remains visible only because the figure covers more of the field, and therefore is more likely to involve an area in which the visual threshold is, for the moment, lower than elsewhere. But, chaotic as the activity of the figure may seem at first, it still obeys some rules which relate to the form of the figure itself. It is these that we are now concerned with.

The "rules" may be summarized as follows. A meaningful diagram is visible longer than a meaningless one: an effect possibly related to the fact that attending to a diagram keeps it visible longer (Pritchard & Vowles, 1960). A straight line tends to act as a unit (i.e., to appear or disappear as a whole) even though it extends across the whole 2 degree field; if the line breaks up, the break is likely to occur at the point of intersection with another line. The several lines of a triangle, square, etc., act independently, with the exception that the activity of parallel lines in a figure is correlated. Jagged diagrams are more active, less stable, than rounded ones: a "good" figure (Koffka, 1935), is more likely to act as a complete unit than a "poor" figure, and there are occasional observations of completion or regularization of a figure. Finally, there are clearly marked field effects, in which the presence of a figure in one part of the field modifies the activity of parts of a neighbouring figure.

These results are illustrated in Figure 3 to 18. Figure 3 shows two curves which are similar except that one is a recognizable profile of a face. When they are seen with the apparent fixation point midway between them, the left curve, without meaning, fades faster and is absent more frequently than the right. Figure 14 combines three meaningful symbols: a "4," a "B" and a "3." Fading of the parts of this complex does not occur at random; almost all the time, when any part of the figure is present, it includes one or more of the symbols, complete. Similarly in Figure 16: the meaningless superimposed lines, over the letter "B," act independently of it, and fade more frequently.

Figures 4 and 5 are configurations which behave in such a way as to emphasize the importance of linear organization. This may be horizontal, vertical, or diagonal, but the horizontal is usually predominant. In Figure 4, whole rows of squares may disappear together, leaving one row intact; in Figure 5, a more or less random collection of dots, there is a strong tendency for the dots to organize themselves, so that a line of dots such as that running from A to B may take on unity and repeatedly remain in the field when the others have disappeared. For one observer, one of the rows of Figure 4 at times acquired a further unity which is hard to describe: the squares within the row remained fully distinct visually, but the row became one thing, separate from the other parts of the figure. Possibly this was one of the three-dimensional depth effects discussed below, but the observer could not be certain on the point.

With the diagrams of Figures 6, 7, and 8, the independence of separate straight lines making up a more complex figure is very striking. Figure 6 shows two series of events which might occur with triangle and square respectively. Lines act as units. It is very seldom that an incomplete one is observed, except where a slight trace may occasionally remain at an

intersection with another line. None of our data supports the assumption made elsewhere (Hebb, 1949) that it is the angle or corner that is a perceptual element. In these figures, again, the influence of parallel lines on one another is evident since opposite sides of square or hexagon (at the left in Figure 7) remain together too frequently for this to be explained as coincidence, whereas with the square it is rare for two adjacent sides only to remain. This parallel-line effect is most striking with the Necker cube; in addition, when the cube is seen in three dimensions (as it always is with the stabilized image), surfaces which are separate but in parallel planes act frequently together. The front and back of the cube may remain in sight, for example, while the other edges (the lines which connect the squares which constitute front and back faces) have disappeared. The parallel-line effect is not invariable, of course, and still less the parallel-surface effect: in addition to complete inversion of the cube (which occurs with the stabilized image as with normal vision) there may be a partial inversion, the same surfaces being seen at right angles to each other.

Our emphasis has been on the independent action of parts of a complex figure, but the figure can also—less frequently—act as a whole, appearing and disappearing as a single unit. The probability that it will do so is principally determined by its shape. A circle, or a diagram such as those of Figures 9 and 10, is relatively stable and quiet, whereas another, as in Figures 11 and 12, is quite unstable and likely to produce an effect of violent motion, as the separate parts appear and disappear in rapid succession. In general, the pattern composed of rounded curves is less active than a jagged one, and more likely to act as whole. The difference between smoothness and jaggedness appears dramatically in a single pattern such as that of Figure 13, in which the angular parts are likely to be active and unpredictable and the rounded parts to form a more stable unit or part figure. This effect is clearly related to the "good' figure of Gestalt psychology, but it must be said that even the circle, the good figure *par excellence*, frequently acts as though composed of separate perceptual elements (see discussion of Figure 17, below). We have in fact found no other extended figure than an uninterrupted straight line which reliably acts as a unit.

The behaviour of wholes is further illustrated by the diagrams of Figures 14, 15, and 16. We have already reported that Figure 14, containing three symbolic patterns, tends to break down in such a way as to leave one or more of the symbols intact. Here an effect of meaning and past experience is evident: similarly in Figure 16, where the "B" tends to remain for longer periods than the hatching lines, and even when they are present, the "B" is seen in a separate plane nearer the observer, as a

separate entity. The diagram of Figure 15, however, shows that the effect can occur with a figure which lacks both meaning and goodness of form: the closed loop also tends to act as a whole though it is quite irregular.

Figure 17 illustrates a field effect which has been observed repeatedly. There is a marked influence of one of the two figures on the other, seen in two ways. First, the parts of the triangle and the circle which are nearest to each other frequently remain visible while the other parts disappear (Figure 17, first example) and second, less frequently, a side of the triangle which remains is accompanied by an arc of the circle which is "parallel" to it (Figure 17, second and third examples). This, with the tendency of parallel lines to act together which was mentioned earlier, seems clearly to show the existence of an influence of a visual object which extends well beyond the actual area of stimulation.

The final illustration, Figure 18, concerns a completion phenomenon which occurs in several ways, including the special case of closure. When a diagram such as that of Figure 9 or Figure 10 loses one of its limbs, we have obtained several reports of a transient closure which is diagrammed in Figure 18. This appears to be a clear case of production of a better figure, and to it we may add the report of one observer that a slightly irregular hexagon became definitely regular. (On the other hand, a circle or other regular figure may be temporarily distorted, with an equally definite change of shape (one observer). The effect is similar to the perceptual distortions reported by subjects who have just come out of "isolation" (Heron, Doane & Scott, 1956).) A second example of completion is found in the hallucinatory addition of an eye to the profile of Figure 3 (one observer, but confirmed by a second observer with another profile figure).

Thirdly, a case which is perhaps equivocal as an instance of completion, but is of considerable interest and one which also brings us to our final topic, of depth effects. With the hexagon as presented in Figure 7, left, we have obtained reports of a "strong cube impression," the hexagon being perceived as the outline of a cube in three dimensions. The cube, also, is seen to reverse as the Necker cube does. The diagram at the right of Figure 7 shows how this may occur; the dotted lines do *not* appear in vision, but the figure acts in other respects as if they were present. In this sense, at least, there is completion.

Depth effects are ubiquitous. When the hexagon just referred to is seen as a two-dimensional figure instead of a cube, it is still clearly in a different plane from that of the background: nearly always above the surface, or closer to the observer. The effect is the same whether the figure is brighter than the ground or darker. The squares of Figure 4

have the appearance of a waffle iron, as protrusions from the surface (or, for one observer, occasionally as depressions); a row of circles of about the same dimensions looks like a row of craters of small volcanoes. The tridimensionality of the Necker cube is much more definite than with ordinary vision; with prolonged viewing it may deteriorate from the appearance of regular cube, but is still definitely in three dimensions, the interior connecting lines appearing like wires strung over and under each other.

Comment

The phenomena that have been described bear directly on two theoretical approaches to perception: Gestalt theory (Köhler, 1929; Koffka, 1935), and the theory of cell assemblies (Hebb, 1949; Milner, 1957) or trace systems (Lashley, 1958). On the one hand, Gestalt ideas concerning the phenomena of perception find further new support; on the other, an independent action of parts even of good figures demonstrates that an exclusively holistic treatment of the percept is not sufficient, so that the explanatory conceptions of Gestalt theory require modification. We believe that the data offer support to both approaches, and qualify them to a greater or less extent; it is too soon to go into detailed analysis, but we may say in general that the holistic ideas become more compatible with analytical ones than was evident previously.

The Gestalt closure that has been described (Figure 18) is most clear-cut and unambiguous, comparable only to what has been observed in cases of hemianopia (Fuchs, 1920; Lashley, 1941). There is clear evidence of the functional meaning of the conception of the "good" figure; of the functioning of the whole as a perceptual entity, distinct from part functions; and of groups as entities, and of similarity and contiguity as determinants of grouping. Finally, we have found evidence of marked field effects.

But with this we have found an extraordinary action of parts, independent of the whole. In the conditions of the experiment, this action tends to predominate over the whole in a way that never occurs in normal vision. The phenomena described, we believe, make inevitable the conclusion that perceptual elements (as distinct from sensory elements: Hebb, 1949) exist in their own right. In conformity with Gestalt ideas, these are organized entities, and the conclusion to be drawn here, perhaps, is not that Gestalt emphasis on organized wholes is erroneous but rather (*a*) that the wholes in question are often simpler ones than are usually discussed—that is, straight lines or short segments of curves—and (*b*) that the more complex wholes, such as square or circle, are syntheses

of simpler ones though they may also function as genuine single entities. The earlier literature treated perception-by-parts and perception of wholes as antithetical, mutually exclusive ideas. In retrospect, one seems that such a theoretical opposition is quite unnecessary, logically; and our data show that both conceptions are valid and complement one another.

The action of parts that has been described is also a very considerable confirmation of the theory of cell assemblies, in its main lines. As we have said above, the data show a need for revision, no support being provided for the idea that an angle or an intersection of lines is a perceptual element. Revision or development of the theory becomes necessary in other respects; for example, to account for the unexpected influence of contiguity as such, seen with Figure 17 (see above). In general terms, however, the phenomena confirm the earlier analysis (Hebb, 1949) to a very surprising extent.

Today there are further data to support this approach. Apart from the present experiment, we may cite the auditory "holding" demonstrated by Broadbent (1956), and the phenomena of serial order in visual perception (Mishkin & Forgays, 1952; Orbach, 1952; Heron, 1957; Kimura, 1959; and Bryden, 1960). All are intelligible in terms of a semi-autonomous activity of closed systems in perception but unintelligible when perception is regarded as a simple input system, and the concept of cell assembly or trace system becomes less remotely speculative than it may have seemed at first, and closer to the realities of behaviour. Further experiments of the kind we have reported, with the use of stabilized images, should make it possible to specify in more detail the properties of these closed systems and so provide a new understanding of the perceptual process.

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TACHISTOSCOPIC RECOGNITION OF NON-ALPHABETICAL MATERIAL[1]

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RECENT STUDIES WHICH COMPARE tachistoscopic perception in the right and left visual fields have concentrated on alphabetical material such as words and letters. The present report shows what happens when non-alphabetical material, such as simple geometric forms, is used. The data obtained have a direct bearing on the problem of serial order, and a major aim of this report is to relate them explicitly to a possible mechanism for temporal integration.

If a row of letters is presented tachistoscopically to a subject, and he is asked to report the letters he saw, he tends to report the letters in a left to right order. In addition, the subject reports the letters at the left of the series more accurately than the letters on the right (Heron, 1957). In Heron's experiment, the stimulus objects appeared in both visual fields simultaneously. If, however, alphabetical material is presented in only one visual field at a time, that appearing in the right field is more accurately recognized. This has been shown for both English words (Mishkin and Forgays, 1952) and for letters (Heron, 1957).

The results obtained with non-alphabetical material, such as geometrical forms and nonsense shapes, contrast with those found with alphabetical material, such as English words and letters. Both Heron (1957) and Terrace (1959) have found that single forms are recognized equally well in the two visual fields when they are presented randomly in either one field or the other. This is quite different from the results obtained with alphabetical material.

Heron (1957) has interpreted these phenomena as being due to the establishment of some sort of facilitation which is closely related to the type of eye movements made while the subject is learning to read. Since one does not have as much experience in reading non-alphabetical material as alphabetical material, there presumably would not be the same tendencies towards eye movements established for forms as there are for letters.

There is some evidence, however, which suggests that this interpretation is incorrect. Kimura (1959) presented four geometrical forms

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arranged in a square centred at the fixation point, and found that the relative frequencies with which they were recognized in each position was the same as for letters appearing in the same positions. Her conditions, however, are not strictly comparable to those used by earlier workers.

The purpose of the present study was to find out more about how the perception of tachistoscopically presented geometrical forms compares with the perception of letters under various conditions. Such information is obviously crucial to any theory which relates the phenomena of tachistoscopic recognition to eye movements specifically related to reading experience. If these eye movements are specific to letter material, as Heron suggests, one would expect to find differences between the perception of forms and of letters. In addition, the results of this study shed some light on the problem of serial organization.

Three experiments are described: the first deals with the recognition of geometrical forms presented in both visual fields simultaneously; the second with the recognition of forms presented successively in one field or the other; and the third with the effects of manipulating the order in which the subject reports the material on the recognition scores.

Method

The stimulus material consisted of 16 upper case letters and 12 outline geometrical forms, of the same size as the letters. These letters were arranged on 3" × 5" white cards for presentation to the subjects. The letters were typewritten in pica type, and the geometrical forms were drawn on the cards in India ink.

The stimulus material was presented to S with a Gerbrands mirror tachistoscope. Before each exposure S was asked to fixate a dot on the pre-exposure field which corresponded to the centre of the stimulus card. After the exposure, S reported the material that he had recognized to the experimenter orally. At no time was S informed whether his responses were correct or not.

Experiment I

The first experiment was performed to determine how subjects report geometrical material when it is presented in both visual fields simultaneously. Data on a comparable series of letters were also obtained.

Two sets of stimulus material, one with letters and one with geometrical forms, were used. The letter material consisted of a series of 16 cards, each with a row of eight evenly spaced letters situated along the horizontal meridian and centred at the fixation point. The position of the letters on the cards was randomized so that each letter appeared in each of the eight positions an equal number of times. The row of letters subtended a total visual angle of 3° 7′. The geometrical material consisted of a similar series of 24 cards, each with a row of six geometrical forms (square, triangle, inverted triangle, star, etc.). Each form appeared in each of the six positions an equal number of times. The row subtended a total visual angle of 2° 30′.

A group of 25 Ss was shown the letter material, and 15 the geometrical material. The exposure time for the letter material was 50 msec.; for the geometrical material, 80 msec. Different exposure times were used for the two groups in order to obtain a comparable percentage of stimulus objects recognized.

TABLE I
MEAN RECOGNITION SCORES FOR SIMULTANEOUS PRESENTATION

Type of material	N	Maximum score per side	Visual field Left	Visual field Right	Total	t_{l-r}
Letters	25	64	27.84	18.60	46.44	5.30*
Forms	15	72	28.00	16.14	44.14	5.67*

*$p < .01$.

RESULTS

The results are summarized in Table I. A *t*-test for differences between correlated samples was used to determine differences between recognition scores for the two fields. Significantly more of the objects appearing in the left visual field were correctly identified with both types of material.

Subjects also tended to report both letters and forms in a left to right order; that is, the first object reported was at the left of the row, and each succeeding response was to an object further to the right. In order to quantify this tendency, a measure of order of report was devised. Each sequence of objects reported by the subject can be examined and classified as to whether the subject is reporting the objects from left to right or from right to left. If a subject reports *n* objects correctly on any given trial, there are *n*-1 such sequences to be examined. The order of report score can then be defined as the proportion of all such sequences in which the subject uses a left to right order. If the order of report is always from left to right, this measure takes a value of 1.00, while if the order is always from right to left, it takes a value of 0.00. A score of .50 indicates that the subject is picking out the objects at random, without any consistent ordering tendencies. The median order of report score for subjects shown the letter material was .76, while the median for subjects shown the form material was .73. In each instance, only one subject obtained a score less than .50; the binomial expansion shows that both groups have significantly more scores above .50 than would be expected by chance ($p < .01$ in both cases). A Mann-Whitney test reveals no significant difference between the two groups in order of report score.

In this experiment, then, forms appear to be recognized in the same way as letters, a result that would not be predicted from Heron (1957), but is in agreement with the data Kimura (1959) presents for geometrical forms.

EXPERIMENT II

In the preceding experiment, it was shown that the recognition of both forms and letters follows much the same pattern, when the material is exposed in both visual fields simultaneously. What happens, however, when geometrical forms are pre-

sented in only one visual field at a time? Although there is some evidence that single geometrical forms are recognized with equal facility in both fields under these conditions, we do not know what happens when groups of forms are presented in this manner. Experiment II was designed to answer this question.

Two sets of stimulus material were used in this experiment. In both sets, a horizontal row of three geometrical forms appeared either to the left or to the right of the fixation point. In one set, the inner side of the form nearest the centre was 0° 7′ from the fixation point, and the row subtended a total angle of 1° 8′. In the second set, the inner form was 0° 37′ from the fixation point, and the row subtended a total angle of 1° 34′. The forms in the second set, therefore, appeared somewhat further away from the fixation point than those in the first set. There were 24 cards in each set, and each form appeared in each of the six positions an equal number of times. The exposure time for this experiment was 60 msec. Fifteen Ss were shown the first set, and 16 the second set.

Results

The results of this experiment are summarized in Table II. Differences in recognition score were tested with *t*-tests for correlated means. There were no significant differences in mean recognition scores in the two visual fields between the two groups, and the scores for the two groups have been pooled.

TABLE II

Mean Recognition Scores for Successive Presentation

Material	*N*	Maximum score per side	Visual field Left	Visual field Right	t_{l-r}
Smaller forms	15	36	14.13	14.73	0.77
Larger forms	16	36	16.81	16.00	0.78
Combined	31	36	15.52	15.39	0.20

The geometrical material was recognized with equal facility in both visual fields. Under these conditions, therefore, the recognition of letters and forms differs, as alphabetical material is recognized more easily in the right field (Forgays, 1953; Heron, 1957; Mishkin & Forgays, 1952). The subjects, however, still tend to report the material in a left to right order. The median order of report score for the 31 subjects was .71. Only four subjects obtained scores less than .50; this is significantly fewer than would be expected by chance ($p<.01$).

Experiment III

It has already been mentioned that Ss generally report tachistoscopically presented material in a left to right order. What happens when the sequence of reporting the material is manipulated? The significance of some of the above results may become clearer if the effect on recognition scores of changing the order in which the S reports the material is studied. Experiment III was designed to

provide an answer to this question. In the experiment, Ss were instructed to report the material either from left to right, the usual order, or from right to left.

The stimulus material for this experiment was the same as that used in Experiment I. A total of 28 Ss were tested; 14 were shown the alphabetical material, and 14 were shown the geometrical material. Immediately after the exposure of the stimulus card, S was instructed to report the material either from left to right or from right to left. The instructions as to order were given post-exposurally in order to control for pre-exposural attentional factors.

Each card was presented twice, once with left to right ordering instructions, and once with right to left instructions. The exposure time for the geometrical material was 80 msec., and for the alphabetical material, 50 msec.

Results

The results of this experiment are shown in Table III. Differences in recognition scores were tested with a *t*-test for correlated samples. With letter material, the order in which the subject reports the material does

TABLE III

Mean Recognition Scores for Differing Orders of Report

Type of material	Order of report	Maximum score	Visual field: Left	Visual field: Right	Total	t_{l-r}
Letters	L to R	64	27.86	15.86	43.71	4.08**
Letters	R to L	64	26.14	14.22	40.36	3.77**
Forms	L to R	36	13.79	9.64	23.43	3.48**
Forms	R to L	36	10.29	13.43	23.71	2.80*

Note: The *t* between total L to R score and total R to L score is 2.95** for letters, and 0.11 for forms.
*$p < .05$. **$p < .01$.

not have any appreciable effect on the locus of correctly recognized material. However, significantly more letters are reported correctly when the order of report is from left to right than when it is from right to left. This would indicate that subjects found it more difficult to report the letter material from right to left. This is supported by the subjective report of many subjects, that, in order to report the material from right to left, they had to recite the letters subvocally in a left to right order, and then reverse this sequence. In addition, it was observed that subjects took more time to report the material from right to left than they did to report it from left to right.

The results obtained with geometrical forms are strikingly different. Significantly more forms are recognized in the left visual field when the order of report is from left to right, and significantly more forms are recognized in the right visual field when the order is reversed. A 2×6 chi square on the positional recognition scores shows that the two curves

differ significantly ($p<.01$). In further contrast with the results of the letter material, the number of forms recognized in the two conditions is approximately equal.

The order of report scores shows that the instructions did change the order of report. With letter material, the median score for left to right order is .82, while the median score for right to left order is .20. For the geometrical material the comparable scores are .86 and .25.

Discussion

The results indicate that there are important differences between the tachistoscopic perception of alphabetical and of non-alphabetical material. Two different modes of presentation were used in these experiments: consider first the situation in which the stimulus material is presented successively in either one visual field or the other. When this procedure is used, alphabetical material is more easily recognized in the right field (Forgays, 1953; Heron, 1957; Mishkin & Forgays, 1952; Terrace, 1959). On the other hand, previous experiments have failed to find any difference between recognition scores for the left and right fields with non-alphabetical material (Heron, 1957; Terrace, 1959), and the results of Experiment II support this finding.

As has already been mentioned, the few previous studies on successive presentation of non-alphabetical material utilized only one form per exposure. It seemed possible that the superior recognition of letters in the right visual field was due to an interaction of visual acuity and the tendency to report the material from left to right. This might be demonstrated by presenting more than one form on each exposure, since the forms would necessarily be in areas of differing acuity, and could be reported in a left to right order. The results of Experiment II, however, do not support the idea of such an interaction. Mishkin and Forgays (1952) have suggested that the left hemisphere is more efficiently organized for the perception of English words. The results of Heron (1957) indicate that this interpretation should be extended to include alphabetical material in general. Heron (1957) has proposed the alternative hypothesis that the response is dependent upon feedback from eye movement centres, and that this feedback favours recognition on the right side in the case of successive presentation. At this point, we do not have the data available to discriminate between their interpretations.

When the stimulus material is exposed in both visual fields simultaneously, there are also differences between letters and forms, although they are evident only under rather special conditions. In general, material presented in this manner is more easily recognized in the left visual field.

Heron (1957) has shown this to be true for letters, and Experiment I reveals that the same thing occurs with non-alphabetical material.

It is here that the relevance of these experiments to the problem of serial order becomes clearer. The crucial factor producing the results of Experiment I seems to be the fact that subjects tend to report the objects from left to right. If we assume that the traces excited by the stimulus presentation fade rather rapidly with time, then the results become quite understandable. Material appearing on the left is reported early in the response sequence, while much of the material on the right is not reported at all, since the trace has faded below threshold before the response is emitted. Perhaps the most convincing data in support of such an interpretation are those from Experiment III. Geometrical forms appearing in the left visual field are better identified when the order of report is from left to right, while those appearing on the right are better identified when the order of report is from right to left.

On the other hand, the sequence in which the material is reported does not seem to affect the position in which letter material is most easily recognized. Fewer letters are reported when the subject has to report from right to left than when he reports from left to right. More striking, subjects frequently report that they had to repeat the letters to themselves in a left to right direction before they were able to report them in the opposite direction. These results seem to indicate that the trace systems that are excited when letters are tachistoscopically exposed are "polarized" in a left to right direction. In other words, the traces excited by letters which are situated in any position on the screen strongly facilitate traces which correspond to letters situated to the right of them, while they exert little if any facilitation on the traces corresponding to letters situated to the left. The facilitations between traces which are involved in the production of the organized temporal sequence of responses to a series of letters are stronger in the left to right direction—so strong, in fact, that they cannot be overridden by the facilitation caused by the "set" of the subject.

No comparable polarization exists for *spoken* meaningless sequences of letters (though it does, of course, for words, as anyone who has ever tried to repeat a sentence backwards well knows). When the subject is asked to report a series of letters from right to left, he first repeats subvocally those letters he would give had he been instructed to report them from left to right. This subvocalization serves to reconstitute the traces so that they are basically auditory, rather than visual, in character. As comparable polarization does not exist in this case, the subject is able to report them backwards, although the time delay results in the loss of some of the letters.

In his discussion of serial order, Lashley (1951) postulates that the "scanning mechanism," that system which determines the actual sequence of responses, is independent of the specific traces which are being scanned. The fact that the sequential report of spatially organized letters is highly polarized in a left to right direction, while the report of forms is not, indicates that this scanning mechanism is not as independent of the traces to be scanned as Lashley would have us believe. Rather than postulating a system which requires two more or less distinct levels interacting, then, a system which is based on a single level may be more useful for resolving some of the problems of serial order. Although Lashley has vigorously attacked all associative-chain theories of serial order, a theory based on the concept of multiple associations between traces seems to be best suited to data such as those presented here.

Summary

The tachistoscopic recognition of horizontal rows of geometrical forms and letters was investigated in three experiments. Both letters and forms were recognized more accurately in the left visual field than in the right when the material was exposed in both visual fields simultaneously. When forms were exposed successively in one visual field or the other, they were recognized with equal facility in the two fields, a result differing from that previously reported for letters. In both of the above situations, Ss showed a tendency to report both forms and letters in a left to right order.

When Ss were given instructions to report the objects either from left to right or from right to left immediately after the exposure of the material, the locus of optimal recognition for forms changed, but that for letters did not. When the order of report was from left to right, more forms were reported in the left visual field, while more were reported in the right field when the order was from right to left.

These results indicate that immediate memory is an important factor in determining which objects are correctly reported after a tachistoscopic presentation. In addition, the processes involved in recognition of letters seem to be strongly polarized in a left to right direction, while those involved with forms are not. It is suggested that a central association model is more successful in dealing with the general problem of serial order than is a "scanning mechanism."

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CONDITIONING OF COMPLEX VERBAL SEQUENCES[1]

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IN RECENT YEARS several researchers have demonstrated operant conditioning of verbal behaviour. One line of research (Greenspoon, 1954; Greenspoon, 1955; Sidowski, 1954) has shown that, when subjects are required to voice words *ad libitum*, the proportion of plural nouns emitted can be increased by "reinforcing" such responses with a verbal signal (mmm-hmm), a light, or a tone. A second set of investigations (Cohen, Kalish, Thurston, & Cohen, 1954; Taffel, 1955) has demonstrated that the frequency with which one class of pronouns is used, when the task is to form a sentence given a verb and a choice of six personal pronouns to start the sentence, can be reliably increased by saying "good" after sentences employing the desired pronoun.

The operant conditioning paradigm has also been used outside the laboratory situation to influence attitudes (Hildum & Brown, 1956) and to manipulate the rate of emission of a defined class of responses (opinion-statements) in an individual's utterances (Verplanck, 1955).

The response units so far investigated in the laboratory have been of a simple and discrete nature (see Krasner's 1958 review), representing very limited aspects of an individual's verbalizations. The present study was an attempt to condition a complex verbal response.

METHOD

The Ss in this experiment were asked to complete sentences of a standard grammatical form, for example, "This is the table that——." Such sentences may be completed in one of two ways: by making the relative pronoun "that" the subject of the subordinate clause (e.g., This is the table that—has a broken leg), referred to as a Subject response, or by *not* making the relative pronoun "that" the subject of the subordinate clause (e.g., This is the table that—John built), referred to as a Non-Subject response. A Subject completion (i.e., what follows "that") is typically introduced by a verb, and a Non-Subject completion by a noun or pronoun.[3] The

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[3]A word, a phrase, or an entire clause may precede the verb of the Subject completion or the noun (or pronoun) of the Non-Subject completion. In such cases, E can reword the completion so that either a verb for the Subject response or a noun (or pronoun) for the Non-Subject response introduces the completion (e.g., "This is the theory that, for some reason, I don't understand" to "This is the theory that I don't understand for some reason").

Subject completion typically defines an action or state of the "organism" described in the stimulus clause (e.g., This is the lion that escaped from the zoo; This is the mountain that is covered with snow). The Non-Subject completion, on the other hand, introduces a new "organism" and defines an action or state of the new organism on, or in relation to, the organism described in the stimulus clause (e.g., This is the lion that the hunter killed; This is the mountain that I hope to climb). Thus in being "conditioned" to give one type of response, S is being encouraged to direct or relate his verbal reports to either the stimulus organism or a second organism which he is "conditioned" to introduce. It is these characteristics of the response which indicate that the verbal response unit here investigated is of considerable complexity.

The 80 sentences used are reproduced in Table I. They are subdivided into four groups of 20 sentences (trials) each. Each was typed in block letters on 3 × 5 white index cards.

Subjects

The Ss were 65 female college students. Sixty Ss were randomly assigned to one of three groups of 20 each: a Subject group, a Non-Subject group, and a Control group which served as control for both situations. After these 60 Ss had been tested, another five Ss were assigned to the Subject group.

Procedure

The sentences were presented through a Gerbrands tachistoscope. S sat in front of the machine and was told to fixate the screen throughout the experiment: thus she could not see *E* who stood at the rear of the tachistoscope.

The following instructions were read to S: "The purpose of this experiment is to study speed of verbal reactions to visually presented stimuli. It is part of a program of research being done here for the Defence Research Board. I shall flash a number of unfinished sentences on the screen. I want you to pay close attention and whenever a sentence appears, I want you to complete it by adding a few words to it. Please say the first thing that comes to mind. I shall give you two examples of what you have to do: Look carefully at the screen.–Now I have just flashed the sentence 'This is the musician that——.' All you have to do is repeat it and complete the sentence. For example, you could say: 'This is the musician that——I heard over the radio,' if that is the first thing that you think of.

"I shall give you another example. Look again at the screen.–I have just flashed another sentence: 'This is the sign that——,' and all you have to do is repeat it and add a few words, for example, 'This is the sign that——hangs on the door, etc.,' if that is the first thing that comes to mind.

"Don't worry if some sentences appear more than once. Is everything clear?–Don't remove your eyes from the screen because sentences will be appearing rather quickly and they'll be flashed on for one second only, and be sure to answer with the first thing that comes to mind."

The true purpose of the experiment was disguised, and credence for the alleged investigation was added by having *E* place a stop-watch near the machine in full view of S before reading the instructions. Visual rather than verbal presentation of the material was chosen to control experimenter variables such as pronunciation, accent, etc. The first author served as experimenter for all Ss.

The order of presentation of the 80 sentences was systematically randomized for each S by shifting the order of the four groups of 20 trials, but the order of the sentences within each group of 20 remained the same. Of the 60 original Ss, an

TABLE I

List of Sentences Used in the Study

This is the	Battle that——	This is the	Mountain that——	This is the	Theory that——	This is the	Lecture that——
	Door		Skill		Flower		Diamond
	Game		Advertisement	(These are)	Curtains		Butterfly
	Gun		Planet		Problem		Building
	Event		Telephone		Man		Stamp
	Window		Song		Ship		Glass
	Knife		Prophet		Formula		Restaurant
	Key		Ashtray		Country		Ghost
	Lesson		Chair		Hospital		Author
	Story		Turkey	(These are)	Shoes		Teacher
	Record		Boat		Child		Weapon
	Scene		Meeting		Painting		Island
	Lion		Doctrine		City		Farm
	Lighter		Star		Airplane		Lamp
(These are)	Results		Picture		Watch		Design
	Fish		Bank		Streetcar		Church
	Radio		Table		Film		Discovery
	Train		Tooth		Bird		Actor
	Bottle		Review		Singer		Ball
	Automobile		Vase	(These are)	Scissors		Water

equal number in each group received the same order of sentence presentations. After the 80 sentences had been presented, the first 20 were again given, making a total of 100 sentence presentations. The following orders of presentation were used (numbers refer to sentence blocks as shown in Table I): 1-2-3-4-1, 2-1-4-3-2, 3-4-1-2-3-, 4-3-2-1-4.

Each sentence was flashed on for 1 sec., with an interval of approximately 5 sec. passing between S's response to one sentence and the presentation of the next one. There was no pause in proceeding from one sentence group of 20 trials to the next. Symbols were used to record the type of completion given by S to each sentence.

For the Subject group, *E* said "Good" in a flat, unemotional tone whenever S gave a Subject response. *E* waited one to two seconds after S had completed the sentence before saying "Good," which sounded more like a self-reflection on the part of *E* than a verbal message directed at S. For the Non-Subject group, the word "Good" was introduced at the end of any Non-Subject response given by S. The first twenty sentences served to establish the operant level of the response for each S, and only Subject (or Non-Subject) responses to sentences 21–100 were reinforced. The Control group received no reinforcement throughout the experiment.

In order to test S's awareness of the relation between his responses and those of *E*, Ss in the experimental groups were asked the following questions at the end of the experimental session: (1) What do you think was the purpose of the experiment? (2) Did you notice anything about my behaviour? (3) Did you notice that I said "Good"? (4) How did you interpret my saying "Good"? Did it influence you in any way? (5) When do you think I said "Good"? Please try to relate my saying "Good" to any particular type of answer you gave me.

Results

The data for those who at the end of the experimental session were able to state the relation between the experimenter's saying "Good" and their own responses were eliminated from statistical consideration. Three subjects in the Subject group and five in the Non-Subject group did offer hypotheses which were in accord with or closely related to the method of reinforcement. For example, one in the Subject group thought that the experimenter said "Good" whenever she completed the sentence by adding only one word to it. Since adding only one word (a verb) resulted in giving a Subject response, her data were discarded. In short, it was not required that Subjects be able to verbalize the exact grammatical characteristics of the reinforcement procedure, but merely to show a general awareness of when the experimenter said "Good." Thus statistical analysis was carried out on the data from 22 Subjects in the Subject group, 15 in the Non-Subject group, and 20 Controls.

It was also decided not to consider the data for Trials 81–100. These sentences, which were the same as those used in Trials 1–20, led to some confusion among subjects. Some reported that upon the second presentation of a sentence, they purposely tried to give it the same completion as on its first occurrence, others purposely gave different completions, and

some tried to say the first thing that came to mind, whether the completion to the second presentation was the same as or different from that given on the first presentation.

An analysis of the mean number of each form of response (Subject and Non-Subject) among the three groups in the operant level trials yielded an F of 0.46, showing that the groups did not differ from one another in this respect. The two experimental groups also showed no difference in the mean number of reinforced responses (Subject responses in the Subject group, Non-Subject responses in the Non-Subject group) in operant level trials ($t = 0.00$).

The mean number of Subject responses for each block of 20 trials for the experimental and control groups is presented in Table II. The last column gives the mean number of Subject responses per block for Trials 21–80 (the reinforced trials in the experimental group).

TABLE II

OCCURRENCES OF SUBJECT RESPONSES FOR EACH BLOCK OF 20 TRIALS

		Trials				
		1–20	21–40	41–60	61–80	$\overline{\text{R.T.}}$
Subject group	$\bar{X}$'s	9.50	10.50	10.95	10.09	10.51
	S.D.'s	3.39	3.81	3.24	4.39	2.96
Control group	$\bar{X}$'s	9.20	9.20	8.95	8.70	8.95
	S.D.'s	4.24	3.75	4.39	3.16	3.14

The change in the frequency of occurrence of Subject responses from Trials 1–20 to each subsequent block of twenty trials was tabulated for each subject in each group and an uncorrelated t-test was run to see whether there was any difference in the amount of change between the two groups. The t-values obtained are reproduced in Table III. The last column in that table reports the t obtained from comparing the change in the mean number of Subject responses per block of twenty trials from unreinforced (1–20) to reinforced trials (21–80) between Subject and Control groups.

None of the t values reported in Table III is significant, $t_{40} = 2.02$

TABLE III

TESTS OF THE DIFFERENCES BETWEEN SUBJECT AND CONTROL GROUPS IN THE CHANGE IN MEAN NUMBER OF SUBJECT RESPONSES FROM FIRST BLOCK OF TRIALS (OPERANT LEVEL) TO SUBSEQUENT BLOCKS

	df		Blocks of trials			
			Bl 1 & 2	Bl 1 & 3	Bl 1 & 4	Bl 1 & $\overline{\text{R.T.}}$
Subject group *vs.* Control group	40	$t =$	1.03	1.75	0.88	1.61

being required for $p = .05$. (When subjected to the Alexander trend analysis, the between group slopes yield an F of 0.89 which is not significant).

The mean number of Non-Subject responses for each block of 20 trials for both the Non-Subject and Control groups is shown in Table IV. The last column gives the mean number of Non-Subject responses per block for Trials 21–80.

TABLE IV

OCCURRENCES OF NON-SUBJECT RESPONSES FOR EACH BLOCK OF 20 TRIALS

		Trials				
		1–20	21–40	41–60	61–80	$\overline{\text{R.T.}}$
Non-Subject group	$\bar{X}$'s	9.53	11.80	12.74	13.60	12.71
	S.D.'s	4.45	4.25	3.33	3.85	2.96
Control group	$\bar{X}$'s	10.80	10.80	11.05	11.30	11.05
	S.D.'s	4.24	3.75	4.39	3.16	3.14

Table V shows the t values obtained in testing the significance of the differences between the two groups in the change in the frequency of occurrence of Non-Subject responses from Trials 1–20 to each subsequent block of trials.

The t of 1.96 obtained for Blocks 1 and 2 comes close to significance ($t_{33} = 2.03$ is required for $p = .05$); those for Blocks 1 and 3 and Blocks 1 and 4 are significant beyond the 5 per cent level. Considering the reinforced trials as a whole, the difference between the Non-Subject and Control groups in the change in the mean number of Non-Subject responses per block from non-reinforced to reinforced trials yields a t of 2.74, significant at the 1 per cent level. (This finding is also significant when tested by the trend analysis.)

An analysis was made of the differences between the Non-Subject and the Subject groups on the change in the mean number of reinforced responses from operant level trials to each block of reinforced trials. The

TABLE V

TESTS OF THE DIFFERENCES BETWEEN NON-SUBJECT AND CONTROL GROUPS IN THE CHANGE IN MEAN NUMBER OF NON-SUBJECT RESPONSES FROM FIRST BLOCK OF TRIALS (OPERANT LEVEL) TO SUBSEQUENT BLOCKS

			Blocks of trials			
	df		Bl 1 & 2	Bl 1 & 3	Bl 1 & 4	Bl 1 & $\overline{\text{R.T.}}$
Non-Subject group *vs.* Control group	33	$t =$	1.96	2.44**	2.29*	2.74***

*p = .05. **p = .02. ***p = .01.

TABLE VI

TESTS OF THE DIFFERENCES BETWEEN NON-SUBJECT AND SUBJECT GROUPS IN THE CHANGE IN MEAN NUMBER OF REINFORCED RESPONSES FROM THE FIRST BLOCK OF TRIALS (OPERANT LEVEL) TO SUBSEQUENT BLOCKS

			Blocks of trials			
	df		Bl 1 & 2	Bl 1 & 3	Bl 1 & 4	Bl 1 & R.T.
Non-Subject group *vs.* Subject group	34	$t =$	1.20	1.40	2.08*	2.02*

*$p = .05$.

t values obtained are reported in Table VI. The difference between the two groups in the mean change in the number of reinforced responses from Block 1 to Block 2 and from Block 1 to Block 3 is not significant, but that from Block 1 to Block 4 is significant at the 5 per cent level. The last column indicates that the difference between the two groups in the mean change in the number of reinforced responses per block from operant level trials to reinforced trials is significant at the 5 per cent level, i.e., that the change in the mean number of Non-Subject responses per block from Trials 1–20 to Trials 21–80 in the Non-Subject group is significantly greater than the change in the mean number of Subject responses per block from operant level trials to reinforced trials in the Subject group.

When questioned at the end of the experimental session, very few subjects could express a "purpose" for the experiment aside from what the experimenter had told them in the instructions. All experimental subjects indicated that they were aware of the experimenter's saying "Good," but the majority interpreted it as showing satisfaction or agreement with their answers or as a sign of encouragement. When asked to relate "Good" to some type of answer they gave, the reports were varied greatly. Some thought, when the topic was brought to their attention, that the experimenter said "Good" to logical sentences, that is, to common sentences that made sense; others related "Good" to interesting or novel sentences. Some connected it with short sentences, others with long ones, still others with grammatically correct sentences. Finally, there were those who could not relate "Good" to any type of response they gave. Few thought that saying "Good" had influenced them in any way; the majority felt that what they said was the first thing that came to mind.

DISCUSSION

The data offer no explanation why conditioning was clearly evident in one group (Non-Subject reinforced, $p = .01$) but much less conspicuous,

or absent, in the other (Subject reinforced, $.20 > p > .10$), nor why the number of reinforced responses showed a significant increase in the Non-Subject group over that shown in the Subject group ($p = .05$). Since the two experimental groups were shown not to differ from one another in the mean operant level of the response to be conditioned (9.53 Non-Subject responses in the Non-Subject group and 9.50 Subject responses in the Subject group, $t = 0.00$), the possibility that differences in the conditionability of the two groups may have resulted from an initial difference in the frequency of occurrence of the critical response in each group is ruled out. Moreover, since the two experimental groups did not differ from one another in the mean operant level of each type of response (9.53 Non-Subject and 10.47 Subject responses in the Non-Subject group, 10.50 Non-Subject and 9.50 Subject responses in the Subject group, $F = 0.46$), it seems that the difference in the conditionability of the two groups cannot be explained in terms of group differences but in terms of the characteristics of the (different) response being investigated in each group.

One possibility is that the Subject form of response is more amorphous than the Non-Subject form, and hence less amenable to conditioning. A Non-Subject response can be introduced by a limited number of pronouns (seven) and by an unlimited number of nouns. It was noted, however, that Subjects tended to introduce a Non-Subject response by a pronoun rather than by a noun, and that they seemed to favour two or three of the pronouns. Thus the probable number of ways in which a Non-Subject response will be introduced is limited. A Subject response, on the other hand, can be introduced by an unlimited number of verbs, and these verbs can in turn vary with regard to tense. Although the subject can show preference for a few verbs (e.g., using the verb "to be"), the number of probable verbs used to introduce Subject responses is likely to be quite great. Hence, in terms of the number of probable alternatives which can be used to introduce either type of response, the Non-Subject response is possibly more easily conceptualized as a distinctive form of response and accordingly more consistently affected by the experimenter's reinforcements.

Related to this question of the "amorphousness" of the response form is the fact that any pronoun (except "it") and several of the nouns which are used to introduce a Non-Subject response can act as a Non-Subject introductory word for each of the 80 sentences presented. For example, "I," "he," "my father," etc., may be used to begin a Non-Subject completion for "This is the (battle, mountain, theory, lecture, etc.) that——." This is not true of words used to introduce a Subject completion. With the exception of a few verbs (to be, to have, may, can, and a few others),

a large number of Subject introductory verbs are applicable to only a limited number of sentences. For example, "flew" could be used to begin a Subject completion for some sentences: "This is the (bird, butterfly, airplane) that flew———," but not for others: "This is the (mountain, formula, etc.) that———." This greater applicability of a few Non-Subject completion words to a large number of sentences may likewise contribute to the greater distinctiveness of the Non-Subject response form.

Summary

The present study investigated the conditioning of a complex verbal response by means of selective reinforcement. Sixty-five Ss were required to complete 100 unfinished sentences presented tachistoscopically. All sentences were similar in grammatical construction, "This is the table that———" serving as an example. Completions were dichotomized as Subject or Non-Subject responses depending on whether or not the relative pronoun "that" was made the subject of the subordinate clause. *E* made no response during the first 20 trials for all Ss. For Trials 21–100, all sentences completed by a Subject response in one group of Ss were reinforced by "Good." A second group was reinforced for Non-Subject responses; a Control group received no reinforcement throughout the experiment. The change in the mean number of the critical response per block of 20 trials from non-reinforced to reinforced trials, when compared to the performance of the control group on these trials, was significant for the Non-Subject group but not for the Subject group. The Non-Subject group was also found to differ significantly from the Subject group in the change in the mean number of reinforced responses per block of 20 trials from operant level to reinforced trials.

Only eight of the 45 experimental Ss revealed any awareness of the contingency between their behaviour and that of *E*.

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BEHAVIOURAL RETARDATION FOLLOWING BARBITURATE ANAESTHESIA

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CHANGES IN BEHAVIOUR resulting from procedures involving surgical operations under anaesthesia (e.g., cortical ablations, electrode implants, sympathectomy) may be attributable to two separate factors: (1) the intended procedure (ablation, etc.), and (2) the anaesthetic employed. Though the numbers and types of anaesthetics in common use have increased in recent years, investigators have in general assumed that the anaesthetics themselves have no significant prolonged influence on behaviour. They have, thus, tended not to control for the behavioural effects of anaesthesia by keeping the control animals under anaesthesia for the same length of time as the experimental animals. The evidence reported here suggests that such controls may be necessary, at least for some anaesthetics.

In an investigation of the behavioural effects of pancreatectomy, it was incidentally observed that rats sham-operated under Nembutal anaesthesia did not differ in the performance of a conditioned avoidance response from rats that were pancreatectomized under the same anaesthetic, but both these groups performed significantly differently from a normal-control group that was never anaesthetized. Surprisingly, these differences were observed three weeks after the operation when the anaesthetic would be presumed to be completely excreted from the body. These observations suggested that Nembutal anaesthesia itself produces some fairly long-lasting effects on behaviour. This paper reports a formal investigation designed to compare the effects of two different anaesthetics, Nembutal and ether, on the acquisition and retention of a conditioned avoidance response in the rat.

METHOD

Subjects

The Ss in the present experiment were 46 experimentally naïve male albino rats of the Sprague-Dawley strain, approximately 95 days old on the first day of training. They lived four or five to a cage in a constant temperature and humidity room in which a 12 hr. alternation of light and darkness was maintained automatically. All Ss had a three-week adaptation period in the laboratory before the start of the experiment. They were maintained on an *ad lib.* feeding schedule throughout the experiment.

[1]Thanks are due to N. Kalant, Assistant Director of Research, Jewish General Hospital, Montreal, where this study was carried out.

Apparatus

The apparatus was a black shuttle box of the kind used by Mowrer, Miller, *et al.* (Mowrer & Lamoreaux, 1942). The box was 36 in. long, 5 in. wide, and 18 in. high. There was no barrier between the two halves of the box, but a wooden moulding projected ¾ in. into the box from the centre of each side wall, demarcating the two halves. The stainless steel grid floor of each half of the box could be separately charged with a current flow of 1 ma. intensity. This shock served as the US. The stimulus preceding shock (CS) was an ordinary door buzzer mounted at the top of the apparatus, in the centre of the back panel.

Procedure

The 46 animals were divided into four groups as follows: (1) a control group of 12 animals, (2) a Nembutal experimental group, N 22, of 14 animals, (3) another Nembutal experimental group, N 4, of 10, and (4) an ether experimental group, E 4, of 10. The Ss were assigned to the first two groups in such a way that their mean weights and weight ranges were approximately equal. The last two groups were matched subject by subject for weight.

The control group was given an intraperitoneal injection of physiological saline, while Group N 22 was given an intraperitoneal injection of Nembutal (50 mg./kg. body weight). Ss in Group N 22 went into anaesthetic coma for approximately 40 min. and were permitted to recover normally. Training for both these groups began 22 days later. Group N 4 was anaesthetized in the same manner as Group N 22. Group E 4 was given an ether anaesthetic, each S in this group being matched with a S in Group N 4 for the duration of anaesthetic coma.[2] Training for these groups began 4 days later.

A day before the start of training, the animals were placed individually in the apparatus and permitted free exploration for a period of 5 min. During this period *E* recorded the number of times S crossed from one side of the apparatus to the other. This constituted a measure of spontaneous activity.

Training consisted in the presentation of the buzzer, followed, 5 sec. after its onset, by the shock, both of which were terminated when S ran to the other side of the apparatus. This was considered an *escape* trial. If S crossed the mid-line of the apparatus before the onset of shock, the buzzer was terminated immediately. This was considered an *avoidance* trial. The interval between trials was 40 sec. Each animal was given 20 trials per day until a criterion of 10 consecutive avoidances, on the third day of training or thereafter, was reached. Thus, each S was given a minimum of 50 training trials. Response latencies were recorded to the nearest .10 sec. by a stop watch.

Extinction trials for each animal began on the day after it attained the criterion. Each extinction trial consisted in the presentation of the buzzer for a maximum duration of 5 sec.; shock was not given even if S did not respond. If S crossed the mid-line of the apparatus before the end of the 5 sec. period, the buzzer was terminated immediately. Each animal was given 10 extinction trials per day for 10 days, or a total of 100 extinction trials, whether or not it was still responding to the CS.

Results

A Kruskal-Wallis one-way analysis of variance for ranks was calculated separately for acquisition and for retention scores, to test the null

[2]I am indebted to Wm. Gallay for technical assistance.

hypothesis that the data of this experiment were gathered from identical populations. For the acquisition data this test yielded an H of 7.08 ($p = .03$) and for the retention data an H of 6.97 ($p = .03$) permitting the rejection of the null hypothesis in each case. Reference to Tables I and II indicates that both groups of animals to which Nembutal was administered showed behavioural effects in both acquisition and retention of the avoidance response. The group to which ether anaesthetic was administered did not show such behavioural effects.

TABLE I

TRIALS TO CRITERION

Group	N	Range	$\bar{X}$	S.D.
C	12	51–80	57.6	7.4
N 22	14	52–164	89.0	32.3
N 4	10	53–300	107.1	72.6
E 4	10	50–75	56.8	6.5

Table I summarizes the learning data, presenting the ranges, means, and standard deviations of trials required to reach criterion. It shows that the experimental animals of Group N 22 on the whole took many more trials to reach criterion and showed more variability than did the control animals. The T value of 130 (Mann-Whitney Ranks Test), however, is not statistically significant. The results of the other two groups, in which training began four days after the administration of the anaesthetics, show that Group N 4 behaved much like Group N 22 which had been trained 22 days after the administration of the anaesthetic. The T value of 74.5, which is significant at the .01 level of confidence, permits the rejection of the hypothesis that the control group and Group N 4 are part of a common population. (One rat in Group N 4 could not be trained to avoid, and training was abandoned for this animal after 300 trials. Excluding the acquisition score of this rat results in a T score of 64.5, which is significant at the .05 level of confidence.) However, Group E 4, for which training began four days after the administration of ether anaesthetic, was not significantly different from the control group in number of trials to criterion, and Group E 4 differed from Group N 22 at the .05 level of confidence (T value of 88) and from Group N 4 at the .01 level of confidence (T value of 71).

Table II presents a summary of the retention data, as measured by number of avoidances during extinction. These results are in general similar to those seen in the acquisition data. During extinction, Group N 22 made significantly fewer avoidance responses than did the control group ($T = 93.5$, significant beyond the .01 level of confidence). Group N 4 also made fewer responses during extinction than the control group;

TABLE II

AVOIDANCE RESPONSES DURING EXTINCTION

Group	N	Range	$\bar{X}$	S.D.
C	12	30–100	74.6	15.0
N 22	14	0–67	24.0	21.6
N 4	9	0–32	9.0	9.5
E 4	10	50–98	80.8	9.8

the T value of 46 is significant beyond the .001 level of confidence. Again, Group E 4 was not significantly different from the control group, but was significantly different from both Group N 22 at the .01 level of confidence and Group N 4 at the .001 level of confidence.

There were no significant differences in spontaneous activity between any of the groups. There were no significant group differences in latency of response measures. All the animals gained weight during the course of the experiment, but weight was not correlated with acquisition or retention scores.

Discussion

The results of this study show that Nembutal anaesthetic affects performance in the conditioned avoidance situation for as long as 22 days after administration of the drug. There is an increase in number of trials to criterion, and a significant decrease in retention of the response. The results also show that, whatever the effect of Nembutal anaesthetic on performance, it is more severe after a four-day interval than it is after a 22-day interval. Some further data which have been collected indicate that the performance of animals trained six and nine weeks after an administration of Nembutal anaesthesia was even less severely retarded than the 22-day group in the present experiment. Thus, it appears that the behavioural effects are not due to some permanent central nervous system damage, but may completely recover within about nine weeks.

The data of the present study also indicate that the coma produced by the anaesthetic is not the important variable in producing behavioural retardation, for rats put under anaesthetic coma with ether and trained four days later do not show retardation in either acquisition or retention. The question which then arises in this: is the important variable in the Nembutal-induced behavioural deviations some factor that is common to all barbiturates? A study using sodium pentothal (Thiopental), another barbiturate, has shown that this drug has behavioural effects similar to those of Nembutal. Lewittes (1959) trained rats in the traumatic avoidance situation, following Thiopental anaesthetic. The eight animals for which training began four days after the administration

of the anaesthetic took significantly more trials to reach criterion than eight control animals ($p<.03$). The eight animals for which training began 22 days after the administration of the anaesthetic also took more trials to reach criterion than control animals ($p = .06$). Both groups of experimental animals made fewer avoidances during extinction than did the control animals ($p = .06$ in each case). Though obtained from small groups of animals, these results parallel those reported in the present study. Whether these effects are specific to the avoidance-response situation, remains to be investigated.

The above findings suggest that continuing caution must be observed in interpreting the results of experiments in which a barbiturate anaesthetic has been administered to experimental animals but not to the control animals. In view of the widespread use of barbiturates as sedatives, somnolents, etc., in human patients, systematic studies of barbiturate effects on human behaviour seem indicated.

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REACTIONS TO NOVELTY AND STIMULUS-CHANGE INDUCED RESPONSE DECREMENT[1]

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WHEN AN ANIMAL IS CONFRONTED with a new situation, it reacts in a characteristic way; the exact responses displayed vary with the species and with the degree of newness or novelty of the situation. In the rat such "novelty reactions" include a wide range of acts, from walking and rearing ("exploring"), through grooming and sitting, to sitting motionless ("freezing"). In a moderately novel situation, walking and rearing acts (locomotion) predominate (Bindra & Spinner, 1958).

It has been proposed (Bindra, 1959) that interference from novelty reactions might account for the response decrement commonly observed in experiments where a response trained in one situation is tested in another, similar but different, situation (for example, stimulus generalization and transfer experiments). One way to test this view is to determine whether pre-training familiarity with (that is, exposure to) the test situation, which would decrease novelty reactions during a later exposure to that situation (Berlyne, 1955), would be associated with lesser response decrement (that is, greater response output).

In a previous experiment (Bindra & Claus, in press) it was demonstrated that rats thus pre-exposed to the test situation showed a higher rate of bar pressing in the test situation than did rats which were less familiar with the situation. However, direct measures of novelty reactions were not obtained in that investigation. In the present study, the frequencies of occurrence of both the trained response (drinking) and novelty reactions were measured. In addition, by arranging to pre-expose animals to different numbers of the stimulus components, the present study determined response decrement in a test situation that offered a different degree of novelty to each of three groups of rats.

METHOD

Subjects and Motivation

Eighteen male hooded rats, about 90 days old at the beginning of the experiment, were used as Ss. They were kept on a 22 hr. water deprivation schedule throughout the experiment.

[1]This paper is based on a thesis submitted by the senior author to the Faculty of Graduate Studies and Research of McGill University in partial fulfilment of the requirements for the M.A. degree. The research was supported by a grant from the National Research Council of Canada (A.P.T. 36).

Apparatus

The basic structure (see Figure 1) was a plywood box, 18 in. long and 8 in. wide. The highest points of the two large walls were 16 in. from the floor; these walls supported a two-part roof which sloped down to 9 in. above the floor in either direction. One side of the roof was made of Plexiglas to allow observation of the animal. The other side of the roof was made of wire-mesh, on which, facing inwards, rested a 4-in. loudspeaker. The speaker was connected to a random-noise generator.

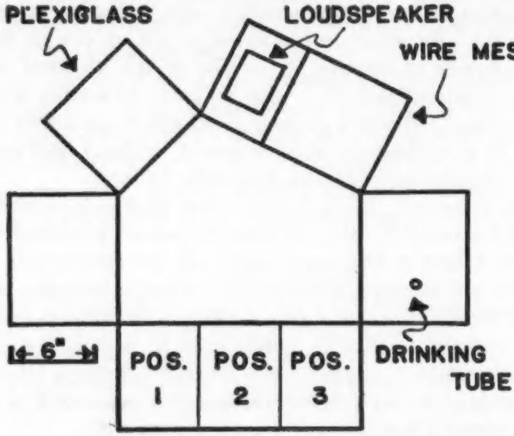

FIGURE 1. *Apparatus*. One of the larger inside walls is represented in the centre of the figure. The floor, the smaller walls, and the roof are shown rotated through 90 degrees around their common edge with the larger wall.

The box was illuminated by a 60 watt lamp placed just above the uncovered part of the wire-mesh. One of the smaller sides of the box had a ¼ in. hole, 2 in. above the floor, through which a drinking tube could be inserted when required; at other times the hole was covered. The visual characteristics of the inside walls could be varied by attaching different cardboards to the walls. The tactual characteristics of the floor could be varied by inserting a Plexiglas or a wire-mesh floor. By turning on or off the random-noise generator, the auditory characteristics of the box could also be changed. Two lines drawn on the floor of the box divided the floor into three equal parts; the location of the animal could be described with reference to these three positions.

We might conceptualize the box as an experimental situation in which all the stimulus elements are categorized into four classes or components, specified visual (v), tactual (t), and auditory (a) elements, and an unspecified remainder (r). The v, t, a, and r stimulus components of the experimental box could be changed to V, T, A, and R, where:

v = black walls; V = striped walls
t = smooth floor; T = rough grid floor
a = 50 db. background sound level; A = 85 db. random noise

r = remaining unspecified elements while drinking tube absent; R = remaining unspecified elements including the presence of the drinking tube

The basic structure was converted into the training situation by covering the inside walls and the floor with black cardboard and introducing the drinking tube. The cardboard on the floor was covered with Plexiglas; no noise was delivered from the loudspeaker. Thus, the training situation may be described as *v, t, a, R*.

The test situation was produced by covering the black Plexiglas floor with 1/16 in. aluminum-painted wire-mesh and the walls with black and white striped cardboard. The stripes were 1 in. wide and extended vertically from the top to the floor of the box. In addition, a random noise of about 85 db. was delivered from the loudspeaker. The drinking tube was present. The test situation may be described as *V, T, A, R*.

There were three pre-exposure situations, resembling the test situation to different degrees. None of them contained the drinking tube. They may be symbolized as follows: Pre-exposure Situation 1: *v, T, A, r*; Pre-exposure Situation 2: *v, t, A, r*; Pre-exposure Situation 3: *v, t, a, r*. It should be noted that t and T do not refer to tactual stimuli exclusively since the change from t to T, from black, smooth floor to aluminum-colored mesh floor, also provided a change in the visual characteristics of the box. Similarly, owing to differences in the texture of the cards used, a change from v to V also provided a change in tactual characteristics.

Procedure

The 18 animals were randomly divided into three equal groups, A, B, and C.

After three days of water deprivation, the pre-training exposure was initiated. Group A animals were exposed individually to Situation *v, T, A, r* for 10 min. per day on three successive days; the animals in groups B and C were similarly exposed to Situations *v, t, A, r* and *v, t, a, r*, respectively.

The three pre-exposure days were followed by four 10 min. training sessions, one on each of four consecutive days, during which the animals learned to drink from the tube in the training situation, *v, t, a, R*. Two animals (1 from group B and 1 from group C) did not drink at all during the first 5 min. of the first training period and were excluded from the experiment at that time.

On each of the two days following training, the animals were tested for drinking in the test situation, *V, T, A, R*. Each test session lasted 10 min. Water was available for the whole duration of the training and test sessions.

The experimental treatment given to each group of animals has been summarized in Table I.

TABLE I

EXPERIMENTAL TREATMENT GIVEN TO THE THREE GROUPS*

Group	Experimental situations: Pre-exposure (3 days)	Training (4 days)	Test (2 days)
A	v, T, A, r	v, t, a, R	V, T, A, R,
B	v, t, A, r	v, t, a, R	V, T, A, R
C	v, t, a, r	v, t, a, R	V, T, A, R

*v, t, a, r and V, T, A, R refer to two sets of visual, tactual, auditory and "remainder" stimulus components.

To start a pre-exposure, training, or test session, the animal was placed in the apparatus at Position 1 (see Figure 1). The frequencies of occurrence of four different activities of the animal were obtained by means of a time-sample method, the reliability and other features of which have been described elsewhere (Bindra & Blond, 1958). The four response categories, defined so as to be mutually exclusive and jointly exhaustive, were the following: D—drinking, licking the drinking tube; L—locomotory reactions (climbing, rearing or walking); G—grooming (scratching parts of body, face "washing," and the like); M—miscellaneous activities, such as sitting and biting parts of apparatus. The activity in which the animal was engaged at the end of each successive 6 sec. interval (indicated by the click of a timer) was noted; this yielded 10 observations per minute. The location (Position 1, 2, or 3) of the animal was also noted at the same time. The behaviour of the animal was recorded for 5 min. only, as preliminary observations showed that the main effects of a comparable stimulus change are observable only for a short time. However, to allow sufficient time for familiarity in the pre-exposure and training trials, the duration of the sessions was fixed at 10 min.

Results

The data consist of 50 observations (10 per min. for 5 min.) made on each animal during each of the pre-exposure, training, and test sessions. The results are described in terms of percentage frequency with which drinking, locomotory reactions, grooming, and miscellaneous activities appeared in the behaviour samples observed.

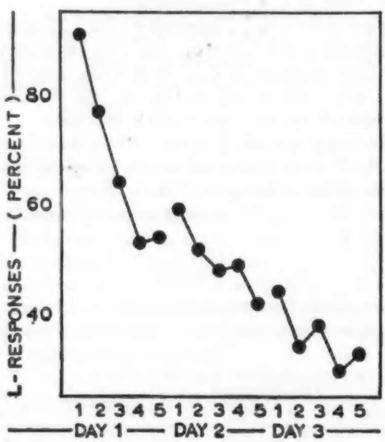

FIGURE 2. The frequency of locomotory reactions over three days of pre-exposure. Each daily observation session is divided into five 1 min. intervals.

TABLE II

GROUP MEANS AND RANGE FOR THE FOUR ACTIVITY CATEGORIES ON EACH DAY OF PRE-EXPOSURE, TRAINING, AND TEST, EXPRESSED AS PERCENTAGES OF THE TOTAL NUMBER OF OBSERVATIONS

			Pre-exposure days			Training days				Test days	
	Group		1	2	3	1	2	3	4	1	2
Drinking	A	Mean				61	73	79	78	62	79
		Range				44–74	60–84	70–86	60–86	50–76	68–90
	B	Mean				62	76	81	71	45	71
		Range				52–74	70–80	66–90	46–84	22–60	56–86
	C	Mean				52	69	77	78	32	66
		Range				30–66	64–76	66–88	62–92	0–58	52–82
Locomotory reactions	A	Mean	62	43	35	31	18	15	13	22	11
		Range	46–76	14–68	8–62	20–46	12–28	10–20	8–20	4–42	6–16
	B	Mean	67	54	36	26	15	9	15	33	14
		Range	34–78	14–78	14–70	14–36	12–22	4–12	10–24	26–46	12–20
	C	Mean	75	61	42	26	21	14	10	51	28
		Range	68–82	28–74	8–72	14–32	14–30	8–24	6–12	32–76	14–42
Grooming	A	Mean	13	17	17	4	5	2	5	5	3
		Range	6–18	4–30	0–30	0–8	0–14	0–4	0–10	0–8	0–10
	B	Mean	14	16	21	6	6	4	4	8	7
		Range	0–46	8–28	2–64	2–8	2–12	2–10	0–10	0–26	2–20
	C	Mean	10	11	8	8	6	4	8	3	1
		Range	6–16	4–18	0–18	0–18	0–18	2–12	0–22	0–8	0–2
Miscellaneous	A	Mean	25	40	47	4	4	4	4	12	7
		Range	10–42	16–70	20–80	0–8	0–8	2–6	0–10	6–20	0–22
	B	Mean	18	29	43	6	4	7	10	14	8
		Range	10–22	14–58	22–72	0–10	2–6	0–20	0–20	6–22	0–16
	C	Mean	15	28	50	14	4	5	4	14	6
		Range	10–26	16–66	20–88	4–42	0–10	0–8	0–16	10–24	4–10

Pre-exposure

While locomotory reactions declined from about 70 per cent to 40 per cent from the first to the third pre-exposure session, miscellaneous responses (mainly sitting) increased from about 20 per cent to 45 per cent, and grooming remained constant at about 15 per cent (see Table II). The incidence of locomotory reactions during pre-exposure followed the pattern, showing intersession as well as intrasession decline (Figure 2), that is typically found in "exploration" experiments (for example, Berlyne, 1955).

Training

The incidences of locomotory reactions and drinking were found to follow complementary courses while the incidence of category G and M activities remained at a relatively stable level (see Table II). Both the decrease in locomotory reactions and the increase in drinking from the first two to the last two training days (see Figure 3) were significant at the .001 level (sign test). The corresponding *p* values for decrease in the G and X categories were .09 and .50, respectively.

Test

There were significant differences (S test; Jonckheere, 1954) between

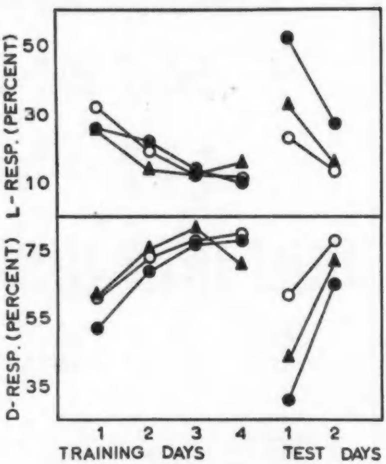

FIGURE 3. The frequency of locomotory responses (upper half of the figure) and of drinking responses (lower half) during training and test. Group A is represented by open circles, B by triangles, and C by closed circles.

the three groups on the first test day with respect to the incidence of both locomotory reactions and drinking (Figure 3). The trend for group A to show fewer locomotory reactions than group B and for group B to show fewer locomotory reactions than group C ($A < B < C$) was significant at the .005 level. The inverse tendency ($C < B < A$) was found with respect to drinking ($p < .01$; S test). Smaller group differences in the same directions were found on the second test day ($p < .005$ for locomotory reactions, $p < .05$ for drinking response).

No differences between the groups were observed with respect to grooming and miscellaneous responses.

A measure of the decrement in the drinking response was obtained for each animal by subtracting the drinking score (that is, the proportion of D responses, as a percentage, of the total number of responses) on the first test day from the mean drinking score on the last two training days. It was found that the decrement, though significant in all groups as tested with the randomization test (Siegel, 1956), was smallest in group A and greatest in C ($p < .005$, S test).[2] An analogous measure for the increment in locomotory responses was also computed. It was found that group A showed the smallest and group C the greatest increment ($p < .005$). These results are summarized in Table III.

TABLE III

GROUP MEANS AND STANDARD DEVIATIONS OF DECREMENTS IN THE DRINKING RESPONSE AND INCREMENTS IN LOCOMOTORY REACTIONS

	Drinking response Decrement*		Locomotory reactions Increment*	
Group	Mean	Range	Mean	Range
A	16.7	10–28	8.3	−7–27
B	31.0	24–41	21.2	16–32
C	46.0	26–86	39.2	21–66

*Decrement-increment is defined as the difference between the mean response frequency on the last two training days and the response frequency on the first test day. The response frequencies were expressed as percentages of the total number of observations.

DISCUSSION

In the present experiment, the stimulus change from training to test situation, namely from v, t, a, r to V, T, A, R, was the same for the three

[2]The data on Rat A6, which of all rats showed the smallest decrement in the drinking response, were excluded from analysis in all cases in which the S-test was used, since significance tables for Jonckheere's statistic are available for samples of equal size only. It may be noted that the levels of significance as reported in the text would not change if any other animal of group A had been excluded instead.

groups; they differed only in their pre-training experience. Group A, that, by the time of testing, had been made familiar with three sets of stimuli (T, A, R), showed less decrement in the drinking response than group B, which was familiar with two such sets (A, R), and group C, which was familiar with only one set (R). This result coincides with the prediction from Bindra's (1959) hypothesis which attributes stimulus-change induced response decrement to interference from novelty reactions.

It might be argued that the observed group differences arose from differential conditioning, during the pre-exposure sessions, of responses facilitating drinking. However there is no reason to assume that responses facilitating drinking (for example, moving towards the place where the drinking tube was later introduced for the training and test sessions) rather than responses interfering with drinking (for example, moving away from the goal section) should have occurred more frequently. In this connection it may be of interest that a crude latency estimate derived from time sampling data, while yielding significant differences ($p < .05$, S test) in the drinking latencies for the three groups ($A < B < C$) in the first test session, did not give a difference in latencies for entering location 3 or the goal section ($p = .50$).

The question of the differences between the groups prior to the completion of training requires some consideration. For one thing, the frequency of occurrence of locomotory reactions was the highest for group C and the lowest for group A on all three pre-exposure days. Though this trend does not reach statistical significance, some such difference was expected on the basis of the fact that the presence of white noise (groups A and B) inhibits locomotion (Bindra & Spinner, 1958). For another, the stimulus change from the pre-exposure to the training situation was the greatest for the animals in group A and the smallest for the animals in group C. The novelty-reactions interpretation would predict that the frequencies of occurrence of locomotory reactions on the first day of training would be ordered $A > B > C$. However, no such differences were observed on this or any other training day; this lack of difference may have resulted from the introduction of the drinking tube with the first training trial.

It may be suggested that the primary decremental effect of stimulus change is on the trained drinking response, and that the decreased frequency of drinking shows itself in some general "vacuum" activities, such as grooming, sitting, walking, and rearing. However, such a hypothesis is not supported by the results since no differences between the groups were found with respect to the increase in grooming and miscellaneous response categories. Only walking and rearing, responses

that contribute to locomotion, the traditional measure of "exploration" (for example, Montgomery, 1951), showed an increase in the test situation. It is also these responses that show the pattern of change (see Figure 2) with continued exposure that is typically seen in exploration experiments. Thus, it seems plausible to conclude that the differences between the groups in drinking decrement are a consequence of the differences between the groups with respect to the increment in locomotory reactions.

It should be noted that in the present experiment it was the locomotory ("exploratory") responses (walking, rearing, climbing) that were associated with response decrement. However, with other kinds or degrees of stimulus changes, other reactions to novelty (for example, freezing, grooming) might be, wholly or in part, responsible for response decrement.

Summary

It has been proposed (Bindra, 1959) that interference from novelty reactions may account for the response decrement commonly observed in experiments where a response trained in one situation is tested in a slightly different situation (for example, stimulus generalization and transfer experiments). As a test of this hypothesis, the rate of a trained drinking response and novelty reactions were measured simultaneously in a test situation that differed in its novelty value for different animals.

Three groups of rats were made familiar with different numbers of stimulus characteristics of the test situation before training was initiated. One group was made familiar with some specified tactual and auditory stimulus characteristics of the test situation, another with the auditory stimuli, and a third group with none of those characteristics of the test situation. After this, the animals were trained on a drinking response, and then the training situation was converted into the test situation. It was found that increase in the occurrence of novelty reactions of the locomotory type, as well as decrease in a trained drinking response, was smallest in the first group and greatest in the third.

It is concluded that novelty reactions are an important determinant of stimulus-change induced response decrement.

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EFFECTS OF EARLY EXPERIENCE ON THE RESPONSE TO WHOLE-BODY X-IRRADIATION[1]

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EARLY HANDLING can decrease the sensitivity of the laboratory rat to a variety of noxious agents and experiential stresses. Pertinent studies have been reviewed by Bovard and Newton (1956), Bovard (1958), and Ader (1959). Some outstanding effects observed in handled rats are lower mortality and less organic pathology under severe, physical restraint (Weininger, 1953); greater viability during terminal food and water deprivation (Long, 1955), and following lethal thiourea dosage (Bernstein, 1956); increased survival time among tumour-bearing rats (Newton & Bly, 1958).

To account for these effects, Bovard (1954) has proposed that handling of the immature rat results in permanent elevation of the threshold for sympathetic reaction to noxious stimuli. Decreased sympathetic reactivity in handled rats should be reflected in reduced adrenal cortical output during stress, relative to the response of nonhandled animals. This has been demonstrated by Weininger (1954) and Levine (1957). Levine (1956) offers the alternative hypothesis that handling is stressful for the rat, and that early experience with stress decreases sensitivity to later stress. In support of this assertion, Levine reports that rats manipulated (picked up) during the early post-natal period responded to cold stress at 16 days of age with greater depletion of adrenal ascorbic acid than did non-manipulated controls. More recently, Levine and Lewis (1959) have shown that neonatal, noxious stimulation in the absence of cutaneous contact with the experimenter is capable of inducing an adrenal response similar to that observed in "picked-up" rats.

A dosage of whole-body X-irradiation (WBI) lethal to 50 per cent of exposed rats within a 30-day period (LD 50/30) is followed by a characteristic set of symptoms: anorexia, loss of body weight, functional and degenerative changes in the gastrointestinal tract, dehydration, vascular collapse, and death of several animals during the initial three to five days after exposure. In the second week additional deaths result from the haemorrhage, infection, and anaemia attending haemopoietic failure. It is well established that irradiation increases pituitary-adrenal activity. Further investigation has revealed that adrenalectomized rats

[1]The authors are indebted to Dr. H. A. Blair, Director, Department of Radiation Biology, University of Rochester School of Medicine, for radiation facilities.

show increased sensitivity to X-rays which, however, can be counteracted by substitution therapy with appropriate amounts of adrenal cortical extract (Edelmann, 1951; Edelmann & Katsh, 1952). Selye *et al.* (1952) report that injection of growth hormone (STH), normally secreted by the anterior hypophysis, can reduce body-weight loss in the irradiated rat.

The present study was devised to test the effect of early handling and cold stress on mortality, ambulatory activity, and the pattern of change in body weight of irradiated rats. A cold-stressed group was included in the experimental design to explore the thesis that post-weaning experience with either handling or stress will produce similar results.

Method

General Procedure

Of four groups of weanlings, one (Group H) received early handling. During the same period, a second group (T) was intermittently cold stressed. Prior to irradiation, two other groups served as controls. One of these (Group XC) was irradiated with Groups H and T. The remaining animals (Group C) continued as non-irradiated controls.

Subjects

Ss were 64 albino rats secured from the University of Rochester colony. All animals were born within a 24 hr. period. To minimize the introduction of extraneous factors, feeding and maintenance were carried out by the experimenters from birth to irradiation. The practice of handling and removing litters during cage cleaning was avoided.

Animals were weaned at 21 days of age and randomly assigned to one of four groups. In each group of 16 rats the sexes were equally represented. Pups were housed individually in wire-mesh cages covered on sides, top, and back with double-thickness wrapping paper. This procedure considerably reduced social interaction with neighbouring rats, and limited the visual perception of extramural objects.

Weanling Ss were started on a diet of ground Purina Lab Chow. Soon, however, many animals began to convert their food containers into living quarters with the result that a large quantity of displaced food was lost through the cage floor. In some instances, rats disposed of their entire supply within a matter of minutes. To ensure *ad lib.* feeding conditions, Purina cubes were introduced and the ground food was gradually withdrawn.

To prevent respiratory infection in animals subject to daily, cold exposure, aureomycin (1 gm. per litre) was added to the drinking water. This treatment which had been administered to all groups, was discontinued at 43 days of age.

Room temperature ranged from 22 degrees to 24 degrees C.

Treatments

Handling. Members of Group H were handled for 10 min. daily in the period 22–43 days of age, inclusive. Handling took the form introduced by Weininger (1953). Since two handlers were involved, they shared the groups equally in order

to control the experimenter variable. Animals were handled each day between the hours of 10 A.M. and 1 P.M.

Cold stress. Cages containing animals of Group T were placed in a walk-in refrigerator each morning for one hour. This procedure was carried out from 22 to 43 days of age. Mean temperature of the cold room was 5 degrees C.

Radiation. At 45 days of age animals were randomly selected from Groups H, T, and XC. They were placed in a Lucite exposure wheel which was radially divided into 16 compartments, each accommodating one rat. The exposure wheel was rotated slowly at a constant speed under the X-ray beam. Animals received radiation through the dorsal surface of the body at an isodose distance (25 in.) from the source. Group C animals were inserted in the exposure wheel and sham irradiated.

A pilot study suggested 650 r. as the LD 50/30 for 45-day-old rats. Rays were generated from a 250 kvp. Picker Industrial X-ray unit. Beam intensity was approximately 18.7 r. per minute for 34 min. and 46 sec. at 250 kv. and 15 ma. Radiation was delivered through an aluminum parabolic filter with a 9 in. diameter and a centre thickness of 14 mm., plus 0.5 mm. of copper sheet, placed at the tube. This combination of factors produces a half-value layer of 2.2 mm. of copper. Dose rate was calibrated with a Victoreen condenser r-meter placed in the compartment where the Ss were later irradiated. This measure was made in air on a grooved Lucite stand at the estimated skin level of the animal.

Tests

Body weight. All rats were weighed at 21 and 43 days of age. Then, 24 hrs. following irradiation, weights were again recorded, and thereafter daily.

Ambulatory activity. A modification of the Hall open field was employed in this test. The apparatus consisted of a circular Masonite platform approximately 5 ft. in diameter and surrounded by a sheet-metal, 3 ft. high wall. A grid of 8 × 8 in. sections and four equally spaced concentric zones were drawn on the platform. On a paper reproduction of the grid floor, *E* traced the path described by each rat during a 1 min. trial. This test was conducted three times: (1) 24 hrs. prior to irradiation, (2) 24 hrs. and (3) 48 hrs. after irradiation.

Mortality. To record mortality, the day was divided into three 8 hr. periods: (1) midnight to 8 A.M. (2) 8 A.M. to 4 P.M., and (3) 4 P.M. to midnight. Rats were checked at the end of each 8 hr. period.

Results

Body Weight

Pre-irradiation. At 21 days of age all groups averaged essentially the same weight (Table I). Three weeks later at conclusion of handling and cold treatments there were no significant differences between the groups. At this time, however, males of Group H weighed an average of 8.2 gm. less than the mean of combined control groups, while Group T males averaged 6.6 gm. less than combined controls.

Post-irradiation. Weight of each animal was recorded two days prior to X-ray exposure. Weights secured following irradiation were computed as percentages of pre-irradiation data. A variance analysis of irradiated animals revealed a significant difference in response as a function of

TABLE I

MEAN PRE-IRRADIATION WEIGHT

	Group	N	Weight (gm.) Age 21 days	Age 43 days
Male	H	8	40.0	148.6
	T	8	40.1	150.2
	XC	8	41.2	156.4
	C	8	40.7	157.1
Female	H	8	37.6	121.3
	T	8	38.3	128.7
	XC	8	38.4	123.6
	C	8	37.9	123.4

type of early treatment ($F = 4.25$, df $= 2$ and 42, $p < .025$), and of sex ($F = 6.26$, df $= 1$ and 42, $p < .025$). The interaction between these two sources of variance, sex and treatment, was significant beyond the .05 level ($F = 3.88$, df $= 2$ and 42). Percentage weight curves, presented in Figure 1, indicate that all irradiated groups lost weight through Day 3. On Day 4, handled and cold-stressed animals began to recoup their losses. A similar recovery did not occur among irradiated controls until Day 5. No significant difference in weight change appeared between irradiated female groups. Since deaths occurred on Day 10, weight analysis was discontinued.

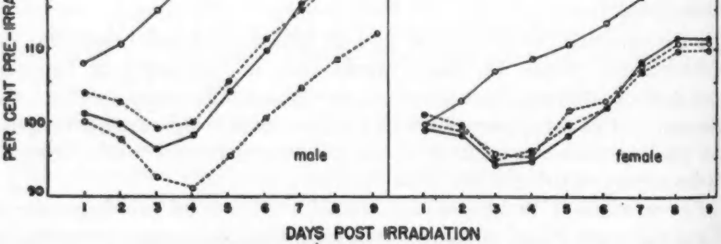

FIGURE 1. Group-mean body weights expressed as percentage of weight recorded two days prior to irradiation of H, T, and XC.

Experimental males remained heavier than controls through Day 9. The extent of weight loss and recovery characterizing handled males during the first nine days following irradiation was closely comparable to that of cold-stressed males. Initially, the latter group appeared to have registered a greater loss than Group H males. However, in the absence of a significant interaction between treatments and days, it is suggested that these two groups responded alike.

Ambulatory Activity

The mean number of sections traversed by each group during pre- and post-irradiation, open-field trials is itemized in Table II. By analysis of variance these data showed a significant effect of trials ($F = 19.68$, df $=$ 2 and 112, $p < .001$). Neither sex nor treatment variances yielded a significant F value. Interaction of treatments and trials was significant beyond the .025 level ($F = 2.63$, df $= 6$ and 112).

TABLE II

MEAN NUMBER OF SECTIONS TRAVERSED IN OPEN FIELD

		Trial			Difference		
		Pre-irradiation	Post-irradiation				
	Group	I	II	III	I–II	I–III	II–III
Male	H	17.1	12.1	10.8	5.0	6.3	1.3
	T	35.3	18.6	18.4	16.7**	16.9**	0.2
	XC	21.1	25.8	16.4	−4.7	4.7	9.4*
	C	15.4	12.6	12.5	2.8	2.9	0.1
Female	H	20.6	17.6	11.0	3.0	9.6*	6.6
	T	30.3	15.6	13.4	14.7**	16.9**	2.2
	XC	24.3	16.0	13.9	8.3	10.4*	2.1
	C	24.9	17.5	18.6	7.4	6.3	−1.1

*$p < .05$. **$p < .01$.

Since all treatment groups were of equal size, critical differences (Lindquist, 1953) at the .05 ($d = 8.51$) and .01 ($d = 11.31$) levels were computed. Applying these to Table II, it is seen that significant reductions occurred in the activity scores of both male and female irradiated controls. All experimental groups showed decreases in activity, with the exception of handled males. It is possible that the substantial drops recorded for cold-stressed groups were a function of their high scores on Trial 1. However, the non-significant F for treatment would indicate that Group T data were not unduly biased by high initial scores. Non-irradiated controls tended to show low activity on Trial 2, though no trial difference among these animals reached significance.

Only in the outer circular zone of the open field did any group have a mean activity score greater than unity. Thus no inter-group analysis in terms of approach to the centre of the field was attempted.

Mortality

At Day 30 post irradiation, there was no significant difference in either group mortality or time of death. Mortality of each irradiated group was approximately 50 per cent.

Discussion

It has been reported that early-handled rats usually show increased weight gain (Bovard, 1958). The present study together with those of Long (1955), Newton (Bovard & Newton, 1956), Scott (1955), Levine and Otis (1958), and Ader (1959) have not produced that effect. Handled and cold-stressed males weighed numerically less than controls at 43 days of age though these differences were not significant. However, a striking weight differential did arise following 650 r. WBI. Though it was expected that all exposed animals would sustain weight loss, analysis of post-irradiation data reveals that male controls lost significantly more weight than their experimental counterparts. On Day 5 post exposure, all groups had begun to regain body weight. But handled and cold-stressed animals showed an earlier recovery. Male rats maintained their advantage throughout subsequent weighings to Day 9, when weight analysis was interrupted.

Weight loss in the irradiated rat is undoubtedly speeded by reduced food intake and increased pituitary-adrenal activity following exposure. Smith and Tyree (1954) point out that changes in body weight and food consumption appear to be dose dependent for a given species. These may well provide reliable indices of radiation damage to the alimentary tract. Though no measure of either food intake or defecation was secured in the present study, it is possible that a contributing factor to the slow rate of weight loss in irradiated males of Groups H and T was greater food intake or less excretion of intestinal contents in comparison with exposed control animals. Experimental rats began to regain weight in advance of controls implying that the former sustained less alimentary damage, permitting earlier recovery of function and better dietary assimilation. This interpretation is in accord with the finding of Ruegamer *et al.* (1954) that early-handled rats assimilate a larger proportion of ingested food than do non-handled.

Generally, early handling affords a protective or anti-catabolic effect in the stressed rat, suggesting increased utilization of endogenous STH. Growth hormone would facilitate cellular repair enabling the handled animal to retain greater body weight than its non-handled control. Sellers

and Barlow (1955) confirm the observation (Selye *et al.*, 1952) that injection of STH combats body-weight loss in the irradiated rat, but report that this hormone fails to improve survival rate. These studies, considered in conjunction with the present data, support the view that early handling enhances the action of STH (Bovard, 1958). Such enhancement is probably dependent on the diminished action of adrenocorticotrophic hormone (ACTH) in handled rats under stress noted by Weininger (1954) and Levine (1957), since there is fairly high agreement that circulating STH and ACTH are antagonistic in their effect on growth of most normal body cells. Administration of ACTH or cortisone to intact, irradiated mice does not reduce weight loss (Smith *et al.*, 1950).

Post-irradiation weight change in handled males was similar in course to that of corresponding cold-stressed rats, lending support to Levine's hypothesis (1956) that either type of treatment is capable of raising the threshold for later stress. In the present study, early experience with a cold environment evidently protected against excessive weight loss in irradiated males. Smith and his associates (1949) have shown that the resistance of adult mice to lethal X-rays is increased by cold stress whether it is preceded or followed by irradiation. Cold stress may benefit irradiated animals regardless of the age when cold is applied, but it remains to be determined whether the protective potential of such temperature change will persist for a longer period in young or adult organisms. Crane *et al.* (1958) report greater food intake but less weight gain among rats kept at 3–5 degrees C. than among controls living at room temperature. If Group T males in the present study consumed extra food, one may surmise that they lost weight at a slower rate than comparable controls owing to the high food content of the alimentary system at irradiation. Also, the radiation response of male experimental groups may have been modified by increased utilization of an unidentified dietary ingredient; in handled rats owing to the assimilation of a high proportion of ingested food; in cold-stressed rats as an outcome of increased metabolic rate (Eddy, 1960).

Weight curves of irradiated female groups showed no effect of either handling or cold exposure. Irradiated females also tended to lose less body weight in percentage of pre-irradiation weight than did irradiated male controls. This sex difference in weight response to X-rays may be explained in part by hormonal function. Progesterone, a female hormone, is known to block release of ACTH (Sayers & Sayers, 1947). Wexler *et al.* (1952) found that female rats had less depletion of adrenal ascorbic acid at one hour post irradiation and earlier replenishment than did comparable males. These investigators also report less body-weight loss in female than in male rats following X-ray exposure.

Haley and his colleagues (1958), in a study of muscle responsiveness in rats given 600 r. WBI, found that fatigue increased and output of work decreased with time after irradiation. Injection of adrenal cortical extract appeared to hasten the development of fatigue in irradiated rats. In the present experiment, handled males were the only irradiated animals which did not show a significant decrease in ambulatory activity. Reduced pituitary-adrenal output in these rats may have contributed to the retention of a relatively stable level of activity.

In the pilot work carried out to provide an estimate of the LD 50/30 for 45-day-old rats, no animal which died within 20 days after exposure showed a reversal of the weight loss which began shortly after irradiation. Deaths were expected in the present study at three to five days after exposure as an outcome of the usual degenerative changes in the GI tract. But all irradiated rats with the exception of one male control began to regain weight by Day 5, and no deaths occurred until Day 10. Most animals which eventually succumbed lost weight rapidly during the 48 hours preceding death. The absence of early GI deaths in exposed controls is probably an outcome of pre-irradiation treatment with aureomycin. Howland, Furth, and Coulter (1950), using more than 1,200 rats, found that clinical doses of aureomycin administered following lethal X-irradiation resulted in an additional five to seven days of life. Further, aureomycin-treated rats regained pre-irradiation weight as early as four days after exposure. In the present investigation, rats received aureomycin for three weeks prior to irradiation only. The pattern of weight gain and mortality observed in these respective studies would indicate that aureomycin introduced in either the pre- or post-exposure period is equally effective.

Summary

Sixty-four weanling rats formed four groups of 16 animals each. The sexes were equally distributed. One group (H) received early handling; a second group (T) early cold stress (5 degrees C.); a control group (XC) received radiation only. Group C served as a non-irradiated control.

At 45 days of age animals of Groups H, T, and XC were subjected to 650 r. of whole-body X-radiation. Results indicated that:

1. No significant differences in weight gain occurred between groups prior to irradiation, though males of Groups H and T were numerically lighter than controls.
2. Following irradiation, Group XC males lost significantly more weight than did either of the experimental groups.
3. Significant differences existed between pre- and post-irradiation, open-field, activity scores for all but Group C, and handled males.
4. Mortality rates between groups were closely comparable.
5. Pre-irradiation, aureomycin treatment apparently eliminated early deaths associated with gastrointestinal damage.

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POSTREMITY IN HUMAN MAZE LEARNING[1]

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VOEKS'S (1948) FORMULATION of the *postremity* principle asserts that the most probable response on trial *n* is the response made upon the last preceding occurrence of the stimuli at that choice point, generally on trial *n*-1. In three manual-maze learning tasks (Voeks, 1948) individual response predictions based on this recency principle were superior to those based on frequency of past occurrence and were far more accurate than would be expected on the basis of chance.[3]

The lack of perfect postremity effect Voeks attributed to (*a*) difficulty in recording the actual "last-made" response, and (*b*) changes in the stimulus situation at the choice point from trial to trial. When the last-recorded response is "incorrect," the signal indicating the incorrectness of the response may elicit additional covert (unrecorded) responses in the presence of many of the same stimuli to which the incorrect response was made. Thus predictions based on the last-recorded response will be inaccurate.

Voeks considers changes in proprioceptive stimuli, arising from postural changes and varied movements, of primary importance since she, following Guthrie (1935), believes that these stimuli comprise a large part of the stimulus situation which becomes associated with a response. Changes in excitement and curiosity (especially on early trials) and changes in external stimuli further augment the stimulus instability.

In a later study on eyelid conditioning, Voeks (1954) attributed the greater success of postremity predictions to the unusually careful control of many of the above sources of stimuli. Waters and Reitz (1950), however, found no effect on the accuracy of postremity predictions when they introduced postural and movement changes from trial to trial, compared to usual training conditions. Apart from the fact that the findings were limited to one stage of learning, both of their conditions would be

[1]This report is largely based on a thesis submitted by the senior author to the University of British Columbia in partial fulfilment of the requirements for an M.A. degree. Part of the material in this report was presented in a paper at the Canadian Psychological Association meetings, June, 1957.

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[3]"Chance" in this paper refers to the expected probability of a response on the basis of random guessing, i.e., $1/n$, where n is the number of response alternatives. Observed frequencies of responses above or below this level, evidence of response selection, may be interpreted in a number of ways. This problem will be alluded to later in the paper.

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expected, on Voeks's theory, to result in wide stimulus differences between trials.

Waters and Reitz (1950) also found the percentage of successful postremity predictions increased as "learning" (occurrence of correct responses) increased. This could be interpreted as a reflection of an increase in (*a*) stimulus stability, and (*b*) the accuracy of recording the last-made responses (as incorrect responses decreased). On the other hand, it might suggest that the success of postremity predictions is largely attributable to the repetition of correct responses, and thus not inconsistent with reinforcement and cognitive interpretations of learning, though the exact extent of the recency effect would still be of concern. Voeks (1948) was content to report the total repetition proportion for all responses, with no breakdown as to their correctness or the stage of learning at which they occurred.

The main aim of the present study was to assess the effect of altering the stability of stimulus sources and the accuracy of recording last-made responses on the efficiency of postremity predictions. Some of the methods Voeks (1954) employed to control the stimulus situation were employed here, along with others felt to be consistent with her theorizing.

Since evidence of postremity effects has been interpreted as supporting Guthrie's (1935) theory of learning and perhaps as embarrassing to reinforcement and cognitive theories (Voeks, 1954; Osgood, 1953; Hilgard, 1956), it may appear that Guthrie's theory is at issue here. The authors think not. Confirmation of the postremity hypothesis would certainly not embarrass this theory. On the other hand, lack of support for Voeks's position would not contradict it since Guthrie was never so explicit as Voeks on a number of matters. Obviously a theory in such a comfortable position is not being tested.

Method

Materials

The learning task was a verbal maze with 12 choice points, each consisting of two alphabet letters (as in Peterson, 1922) presented verbally by *E*. Twenty-four letters were randomly paired, excluding "x" and "z." The order of the two letters in a pair, the order of the pairs in the maze, and the "correct" letter in each pair were likewise randomly determined, with the exception that any meaningful or memory-fixing arrangement apparent to the authors was altered.

S sat at a table facing a wall 4 ft. away, which was entirely draped with black curtains. A tin can, containing a 15-watt bulb and a $\frac{1}{16}$ in. hole in the surface facing *S*, was located 1 ft. in front of the wall at average eye level of seated *Ss*. The bulb could be turned on either by depressing both of two doorbell buttons on *S*'s table or by closing a throw switch on *E*'s table. The position of the doorbell buttons could be adjusted to suit the reach and comfort of *S*'s arms. Depressing the buttons

required little effort. An adjustable chin-rest with table-high elbow-rests on each side was also located on S's table.

E's table, located directly behind and not visible to the seated S, contained the throw switch and a small shaded night-light (7 watt) mounted on a piece of 2 in. high, dull-surfaced black cardboard. Additional dull-surfaced black cardboard covered the table.

Subjects

The Ss were 84 volunteers (44 male, 40 female) from the introductory psychology course at the University of British Columbia. They were randomly assigned to one of four conditions upon reporting for the experiment. After testing, S was urged not to inform others of the nature of the task. He was not told that repetition of individual responses was being measured.

Procedure

Each S was given nine trials in the maze, which in a preliminary study allowed most Ss to make at least nine out of 12 correct choices. Employing a criterion of several successive errorless trials, as Voeks (1948) did, merely ensures perfect accuracy of postremity predictions for the last few trials (Osgood, 1953).

Condition I: Normal training conditions. The room was illuminated by overhead fluorescent lighting. S was asked only to sit at the table and not look back at the experimenter. E read the following instructions:

"I have a rather straightforward learning task here. It consists of pairs of letters, such as 'Z' and 'X,' which will be presented to you a number of times. For each pair, one of the letters is right and one is wrong. Your job is to learn the right one. I will say each pair to you and you will tell me which one of the two letters you think is right.

"Now, the first time I present a pair to you, you will have no idea which one of the letters is right; so you merely guess. I will then tell you whether you were right or wrong. Then the next time I say that pair you will try and remember which one was right. For example, if I say "Z, X" and you guess "X" and I say "wrong," then the next time I say "Z, X" you will try and say "Z."

"There are 12 pairs of these letters and I will go through and say each one to you in turn, from one to twelve. I will go back to the beginning and go through the list several times, the same pairs in the same order. You will try and learn as many of the right letters as you can. Every time you choose a letter I will tell you whether you were right or wrong.

"There is no pattern of right answers, either according to the alphabet or according to the order the letters are presented in. So don't bother to look for a pattern, it will only hinder your learning. Just try and remember which one of the letters is right for each pair.

"The list is a little difficult so don't expect to learn it right away. Don't be discouraged because you can't remember the right answers after only a few trials.

"Now, if you're ready, we'll start. Remember, the first time through the list, you merely guess which letter of each pair is right. Do you understand?"

If S had any questions, every effort was made to see that he understood the nature of the task. S was then given nine trials, with a 10 sec. pause between trials. Each pair of letters was recited in turn by E, S made his response (no time limit), E recorded the response and then said "right" or "wrong." Immediately after this announcement E presented the next choice point; in this way an attempt was made to keep implicit practice at a minimum.

Condition II: Relative stimulus stability. After S was seated the chin-rest and the doorbell buttons were adjusted. The overhead lights were then turned out. All the preliminary Ss reported that when looking at the dot of light which issued from the can they could see nothing else at all.

A reaction-time task was introduced here to remove some of the initial tension, curiosity, and excitement of S, and to familiarize him with the experimental apparatus.

Next S was urged to take a comfortable position with his index fingers on the buttons, and to move as little as possible. He was reassured that this would not be difficult for the short time required (the average time was close to 7 min.).

The instructions given to Group I were read, with the following addition: "One more thing; when I say "press down," please press down both keys and keep them down until I tell you to rest your fingers. During this time please look at the light and try not to move your head. At the end of each time we go through the 12 pairs you will be given a chance to rest your fingers. O.K.? Then press down."

The maze was presented as in Condition I. In addition, S kept the buttons pressed down and looked at the light continuously throughout each trial, and rested his fingers during the 10 sec. pause between trials. No S reported any finger fatigue upon questioning after the testing session.

The various methods employed with this group to keep S's posture constant from trial to trial, to keep his movements to a minimum, to dissipate initial curiosity and tension before training, and to limit variation in external stimuli, should have resulted in greater stimulus stability than in Condition I.

Condition III: Systematic variation of posture. The procedure was identical to that of Group II (including the preliminary task), except for trials 3, 6, and 9. At the beginning of each of these trials S was told to (1) stand up, (2) place his hands on his hips, (3) face 90 degrees to the left ("face the wall to your left"), and (4) turn his head back and look at the same light. The light was turned on during these trials by means of the throw switch on E's table. The trials were conducted as usual, except for the change of body posture. The other six trials were run exactly as in Condition II.

This condition differs from Condition II only in proprioceptive stimulus stability, considered of great importance by Voeks.

Condition IV: Relative accuracy of recording last-made responses. This group was treated in the same manner as the second (stability) group, except that a correction method of learning was used. After each "wrong" response by S, the choice point was immediately repeated, and S gave the "right" response. The choice point was repeated, rather than have S change his response upon hearing "wrong," in an attempt to make the stimulus situation more like that to be encountered on the next trial. Since all last recorded responses were necessarily "correct" in this condition, the recording was more accurate than in the other conditions, according to Voeks's hypothesis.

Results

In scoring, a response was counted as correctly predicted by postremity if it was the same as the last-recorded response on the preceding trial at the same choice point. For each subject the number of correct predictions (out of 12) were totalled for each of the three critical trials (3, 6, and 9,) where the systematic changes of posture were introduced in Condition III.

In order to derive information about the relative efficiency of the predictions not only between the groups, but also between the three critical trials, an application of analysis of variance (taking into account the correlation of scores between trials) described by Edwards (1950, p. 288) was used.

Since the scores were proportions, the angular transformation was employed (Snedecor, 1946, p. 449). The chi square obtained from Bartlett's test of homogeneity of variances on the transformed data was not significant (.05 level).

The results of the analysis of variance are presented in Table I. The *F* ratios for differences between groups and for differences between trials were both significant beyond the .01 level. The interaction *F* ratio was not significant at the .05 level.

TABLE I

ANALYSIS OF VARIANCE OF THE NUMBER OF CORRECTLY PREDICTED RESPONSES

Source	df	MS	*F*
Between groups	3	1201.59	4.64*
Between *Ss* in the same group	80	258.97	
Between trials	2	5683.98	63.95*
Interaction: trials×groups	6	149.23	1.68
Interaction: pooled *Ss*× trials	160	88.88	

*$p < .01$.

Specific differences between the four groups were determined by *t* tests (critical difference formula). The only differences were between Group IV and each of the other three groups (.05 level). The means of the transformed scores converted back to percentages are as follows: Group I, 79.3 per cent; Group II, 77.9 per cent; Group III, 76.2 per cent; Group IV, 88.8 per cent. Efficient postremity prediction was facilitated through the use of the correction method of learning, employed here to increase accuracy of recording last-made responses.[4] No differences in predictive efficiency were attributable to variation in the stability of the stimulus situation between Conditions I, II, and III.

[4]It has been pointed out to the authors that the correction procedure could also be viewed as producing greater stimulus stability. In this condition each choice point was, on all trials, just preceded by almost identical events (i.e., previous choice point, "correct" response, *E*'s "right"), which was not the case in the other experimental conditions where "wrong" responses were not immediately corrected. Thus the superior predictive efficiency in this condition may have been partially or wholly due to this greater stimulus stability.

Results of t tests (for paired cases) between the three trials showed the mean number of correct postremity predictions increased significantly (.001 level in all cases) from trial 3(68.6 per cent) to trial 6(80.5 per cent) to trial 9(90.9 per cent).

Several additional analyses were carried out to determine the relation between successful postremity predictions and the occurrence of correct responses.

(1) An analysis of variance showed, as would be expected, that more correct responses (before correction) were made by Group IV than by any of the other three groups (again there were no differences between Groups I, II, and III), and that correct responses increased in number with advancing trials in all groups. Thus the number of correct responses varied between groups and trials in much the same way as the number of successful postremity predictions did.

(2) These two quantities largely varied together between subjects as well. An r of .80 was obtained between the number of correct responses and the number of successful predictions for the 63 subjects in Conditions I, II, and III (a perfect positive correlation was predetermined in Condition IV by making all last-made responses correct). The data from Conditions I, II, and III were grouped together in this and all further analyses since no differences were observed between these groups in successful predictions or number of correct responses.

(3) For all subjects in the first three groups a total of 1,886 postremity predictions of the incorrect response (when the last-recorded response was incorrect) were made. Of these predictions, 917 (less than half) were correct.[5] On the other hand, when predictions of the correct response were made, they were accurate approximately 90 per cent of the time.

In order to assess the effect of frequency of past occurrence on response repetition (postremity), repetition proportions, for each subject in the first three conditions, were computed for varying frequencies of immediately preceding consecutive occurrences of the response. The mean proportions are presented in Figure 1, for correct and incorrect responses separately. Friedman's non-parametric "analysis of variance" for related samples used on the proportions after 1, 2, 3, 4, and 5 preceding occurrences for correct responses, and after 1, 2, and 3 occurrences for incorrect

[5]Actually, evaluation of the obtained repetition frequency of incorrect responses becomes an involved question. On the basis of some theories of learning (Hull, 1952, for example) one might expect an even lower repetition frequency for incorrect responses than was obtained. On the other hand, if one assumes that all responses are not equally probable before learning in the task, even above-chance repetition of incorrect responses would be explicable by such theories. Space does not permit a discussion of these and many other factors which bear on this issue.

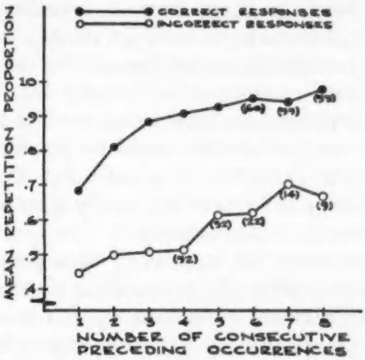

FIGURE 1. The mean proportion of responses repeated as a function of the number of consecutive preceding occurrences of the response. Based on the data of Groups I, II, III (63 Ss). The numbers in parentheses represent N, when this is less than 63.

responses (where every subject was represented) yielded p values of less than .001 and just less than .06, respectively. Thus the probability of the repetition of at least the correct response increased with an increase in the number of immediately preceding consecutive occurrences of that response. The significance of the sharp rise in the remainder of the incorrect responses curve is problematical since less than half of the subjects tested are represented.

DISCUSSION

According to the postremity hypothesis, variations of successful postremity predictions may be due to variations in stimulus stability or to the greater frequency of repetition of correct than incorrect responses (because of differences in accuracy of recording last-made responses). The variation of stimulus stability between Conditions I, II, and III of this experiment did not produce significantly different amounts of successful postremity predictions.

If the variations of successful predictions that were observed were to be attributed to assumed variations of stimulus stability, some account of the direct relation between successful predictions and the occurrence of correct responses would be necessary. Thus the assumption would have to be made that stimulus stability varied directly with the number of

correct responses between trials, between conditions, and between subjects. This assumed co-variation between subjects would be purely *ad hoc*. It might be expected that stimulus stability would vary between subjects, but there is no *a priori* reason to expect that it would vary with the number of correct responses between subjects. A rather involved *ad hoc* accounting for this co-variation might be possible, but the authors feel it would necessarily involve, at some point, the assumption that correct responses are repeated more frequently than incorrect responses, making the entire interpretation redundant.

A similar difficulty arises in explaining, by a postulated increase in stability with advancing trials, the co-variation of successful predictions and correct responses between trials. Here again it would be necessary to assume that correct responses are repeated more often than incorrect responses, producing greater numbers of correct responses with advancing trials. Having made this assumption, there would be little reason to add the concept of stimulus stability.

The greater predictive efficiency of postremity in Condition IV could be attributed to greater stimulus stability (see footnote 4), but it is probably more economical, considering the general lack of support for the effect of stimulus stability, to attribute it simply to the more frequent repetition of correct responses than incorrect responses.

The difference between correct and incorrect responses in frequency of repetition is, in Voeks's analysis of response determination, attributable to the production in the subject of other (implicit) responses by the signal indicating that a response is incorrect; these other responses (unrecorded last-made responses) thus becoming associated with some of the choice point stimuli. However, reinforcement and cognitive interpretations of the effects of reward and punishment are just as applicable to the data as is this Guthrian interpretation.

The demonstrated effect of the frequency of past occurrence upon the probability of response repetition is contrary to the central notion of Voeks's postremity hypothesis. It can only account for this effect to the extent that it is conceived as incorporating the more comprehensive nature of Guthrie's theory, depriving the hypothesis of any separate identity.

In general, the analysis of the postremity effect presented here supports an interpretation of response determination by recency, frequency, and reward (however theoretically interpreted). This is hardly a surprising conclusion. But it does serve to deny that the repetition of a large proportion of maze responses on the following trial (the postremity effect) is unaccountable for by reinforcement or cognitive interpretations of learning.

The indication that the probability of an incorrect response may increase with past frequency, perhaps to an above-chance level (see also Marx, 1941; Thorndike, 1932; and Tuckman, 1933), does raise difficulties for reinforcement and cognitive theories of learning. Above-chance repetition of errors in human learning has been noted in numerous investigations (reviewed in Koppenaal, 1958). A re-examination of the data of this study was therefore undertaken to determine if error repetition was above-chance in any part of the maze; specifically, the possibility of a serial position effect was entertained. Analysis revealed that at the six middle choice points, and before the subject made one or fewer errors on a single trial, incorrect responses were repeated more than half the time by 39 of 63 subjects ($p = .057$, with a two-tailed binomial test). The *ad hoc* searching of the data for this finding renders its statistical significance indeterminate, to say the least. Only further research will determine the reliability of the phenomenon. The complex problems in explaining the above-chance repetition of errors and the increase in repetition with past frequency cannot be further elaborated here owing to space limitations (footnote 5 gives a sketchy indication of the problems).

Summary

The postremity principle states that the most probable response at a choice point in a maze is the same response last made at that choice point. This principle emphasizes the importance of stable stimulus situations, especially proprioceptive, from trial to trial in making successful predictions.

The aims of this study were the determination of the effects of varying the stability of proprioceptive and other stimuli upon postremity effects, and the evaluation of the dependency of successful predictions upon the occurrence of correct responses.

Eighty-four Ss were tested with a verbal maze. Three variations of stimulus stability from trial to trial were employed, with a correction method of learning employed in a fourth condition. The purpose of the fourth method was to obtain more accurate recording of last-made responses, which has been hypothesized as difficult when the last overt response is "incorrect."

The results (*a*) did not support the hypothesized importance of stimulus stability for successful postremity predictions, (*b*) showed that successful prediction was largely due to the repetition of "correct" responses, and (*c*) that the frequency of past occurrence, contrary to the postremity principle, was an important factor in the probability of a response being repeated.

Several incidental findings were mentioned which could indicate the need for further study of the occurrence of incorrect responses.

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SMALL EYE MOVEMENTS OF THE CAT[1]

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IT IS KNOWN that small eye movements are essential for normal human vision. When the image of a single line is stabilized on the retina, the line is seen only intermittently (Ditchburn & Ginsborg, 1952; Riggs, *et al.*, 1953), while more complex stimulus objects appear to be fragmented (Pritchard, Heron & Hebb, 1960). However, the experimenter using acute preparations to investigate the neural mechanisms involved in visual perception has not considered the effects of small involuntary eye movements. Trying to control the stimulus, he either paralyses the animal's eyes or fixes them rigidly so that movement is impossible (for example, Kuffler, 1953; Hubel and Wiesel, 1959; Grafstein, Burns & Heron, 1959). However, the stimulus pattern is presented for periods of a second or less, periods which are so short that small eye movements may be irrelevant. While we have gained considerable information using these methods, it is conceivable that taking eye movements into account might help us to understand more about the neural basis of pattern vision, the organization of the receptive field and the peculiar phenomena which occur during retinal stasis.

The present report gives the amplitude and frequency of the cat's small eye movements. Our evidence suggests that the eye movements of the cat differ from those of the human in a way which is related to the differences in anatomical organization existing between the two species.

METHOD

Four cats were used as Ss. Drops of a 2 per cent solution of methoxamine hydrochloride were put in the animal's eye to retract the nictitating membrane and withdraw the eyelids. After about 10 min., tetracaine hydrochloride (0.5 per cent solution) was added to reduce blinking, followed by a 1.5 per cent solution of methyl cellulose to protect the eyes while the animal was unable to blink. The cat was then anaesthetized with ethyl chloride followed by ether for 10–15 min. (one rather passive individual was not anaesthetized). During this time the cat was put in a 16 × 6 × 6 in. box bolted to the work bench, so that its head protruded through a hole in one end of the box and its legs through four holes in the sides. The legs were firmly anchored by straps, and the head immobilized by rubber-tipped braces placed on both sides and above it. The bottom jaw rested on a wooden platform. Alligator clips attached to the hairs of the right eyelids prevented them from closing.

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After the cat had been firmly fixed in this position, a solution of methyl cellulose, thick enough to be tacky, was put in the right eye and a 1-1.5 mm. mirror chip embedded in a waxed tissue paper disc 2–3 mm. in diameter (Ratcliff & Riggs, 1950) was placed on the temporal side of the pupil, which, under the experimental conditions, was half dilated. As the methyl cellulose solution dried out, the wax paper became so firmly attached to the eyeball that it was difficult to remove at the end of the experiment. A second, 3 mm. mirror was fixed in a lump of plasticine fastened to the shaved nose of the animal, so that both mirrors were in the same horizontal plane.

The method used for photographing the eye movements was similar to that described by Ditchburn and Ginsborg (1953). A vertical slit aperture is illuminated by a collimated beam, as shown in Figure 1. The projector lens L_2 focuses an image

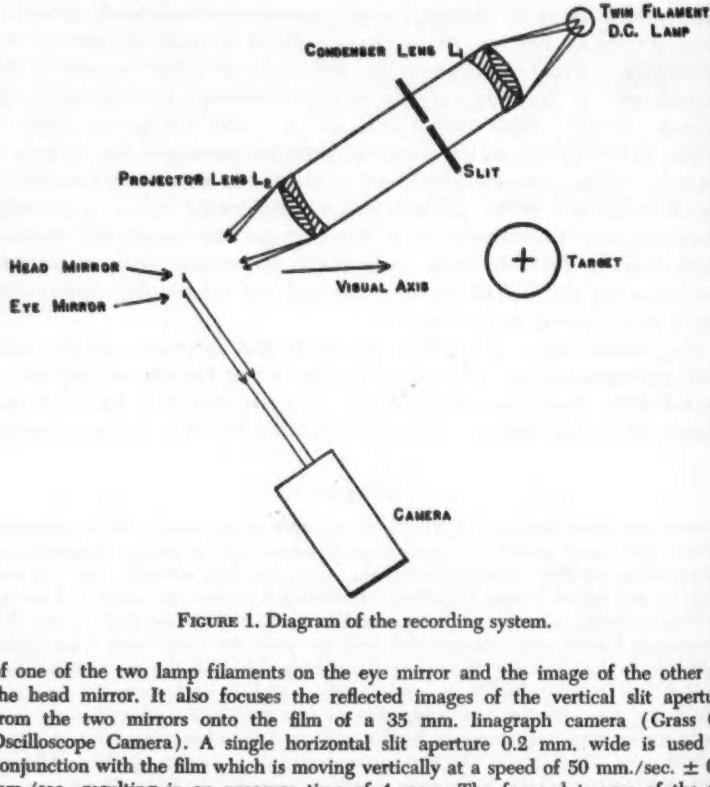

FIGURE 1. Diagram of the recording system.

of one of the two lamp filaments on the eye mirror and the image of the other on the head mirror. It also focuses the reflected images of the vertical slit aperture from the two mirrors onto the film of a 35 mm. linagraph camera (Grass C4 Oscilloscope Camera). A single horizontal slit aperture 0.2 mm. wide is used in conjunction with the film which is moving vertically at a speed of 50 mm./sec. ± 0.3 mm./sec., resulting in an exposure time of 4 msec. The focused images of the slit aperture moving over the surface of the continuous film indicate the horizontal deflections of the eye and head. The difference between the records thus obtained

can be used to measure the horizontal movements of the eye without contamination by head movements. No records were taken until the animal had fully recovered from ether.

In order to keep the beam reflected from the eye mirror in the camera, we had to get the cat to fixate. Fortunately, the animals we used would look for several seconds at certain objects placed in front of them, particularly if some noise was made when the object was introduced (scratching noises were excellent stimuli). The technique used was to introduce an object, and then to align the camera (and, if necessary, the head mirror) so that the images of the vertical slit aperture from the head and eye mirrors both fell on the horizontal camera slit (the focal plane of the two images had previously been determined, and the film was kept in this plane during alignment). The cat's fixated eye movements were then recorded for as long as the reflected beams remained on the camera slit. When the cat looked away, a new object was introduced, and, if necessary, the camera realigned. The objects used were a candle flame, a small stationary light, a rat in a glass jar, the face of an experimenter and a piece of cotton wool. The last three were illuminated by an ancillary light, as the room was blacked out except for the small amount of stray light from the twin filament lamp. All the objects were situated about 50 cm. from the cat.

The eye movement amplitudes were deduced from the photographic records by the relationship $D = X\tan 2\theta$ where θ is the horizontal angular movement of the eye, D is the displacement of the photographic trace and X is the distance between the film and the mirrors on the eyeball and head. ($X = 200$ cm. for accurate measurement of the amplitudes of the higher frequency components while $X = 50$ cm. for drift amplitude measurements.) The records were projected at a magnification of 10 for measuring purposes, and could be measured to 0.5 mm. which limited the sensitivity of the method to about 0.1 min. of arc.

The stability of the system was tested by attaching a mirror to the animal box which, it will be remembered, was bolted to the bench. The photographed movements of this mirror showed that the optical system and camera were rigid and free from vibration.

Results

The results are summarized in Table I, where the eye movements of the cat and the human are compared. Three types of eye movement can be distinguished in the cat:

(1) Slow irregular drifts of the visual axis which vary in amplitude and velocity and which are terminated by a slow reversal of direction. The mean drift velocity between reversal periods is 30 min. of arc per second (30 min.arc/sec.), while the median value is 20 min. arc/sec. The amplitude can exceed 2 degrees although the net displacement of the visual axis is usually contained within 25 min. arc for periods of a few seconds. It was impossible to record mean drift amplitude because of the number of occasions on which the trace drifted off the camera face.

(2) Tremor, consisting of small movements of irregular frequency and amplitude which are recognizable between 2 and 40 cycles per

TABLE I

COMPARISON OF SMALL EYE MOVEMENTS OF CAT AND HUMAN*

Movement	Cat	Human
Drift		
Mean amplitude	25 min. arc approx.	3.7 min. arc
Maximum amplitude	>2°	9.0 min. arc
Mean velocity	30 min. arc/sec.	1 min. arc/sec.
Tremor		
Mean amplitude	0.4 min. arc	0.3 min. arc
Median amplitude	0.3 min. arc	0.3 min. arc
Maximum frequency	40 c/sec.	150 c/sec.
Flick		
Mean amplitude	35 min. arc	11 min. arc
Interflick period	Very large	0.03–5.0 sec.
Duration	0.04 sec.	0.03 sec.
Mean velocity	13°/sec.	10°/sec.

*Human data from Fender (1956).

second (c/sec.). The mean and median amplitude values for all excursions in this range are 0.35 min.arc and 0.25 min.arc respectively. Figure 2 shows the relation between frequency and amplitude (measured peak to trough). The results are limited in some respects, however, since our

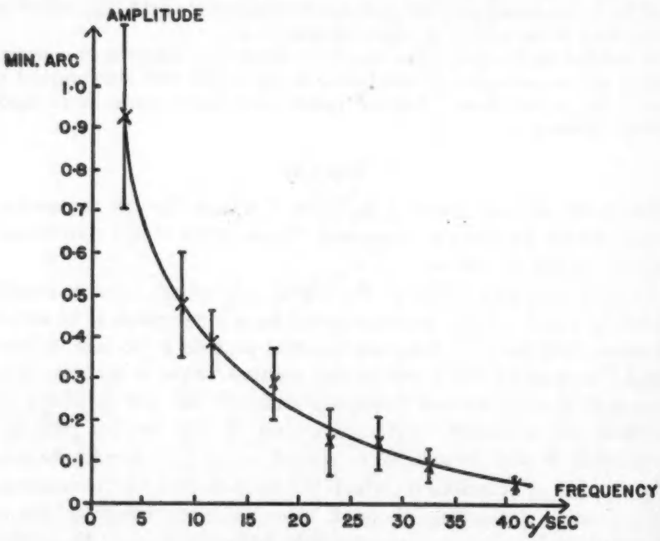

FIGURE 2. Graph showing the relation between frequency and amplitude of the small oscillatory movements.

system was not sensitive enough to record tremor movements faster than 40 c/sec. because of their small amplitude, while below 2 c/sec. the movements become confused with drifts.

(3) Saccadic movements or rapid flicks occur, but, as only seven such events have been recorded during the whole of the present project, it is not meaningful to record an interflick period.

The maximum head movements recorded under our conditions are 1 min.arc and seem to be related to the animal's pulse. They are regular and, in consequence, can easily be corrected for in the eye movement trace.

In comparing the cat and human drift movements, it should be noted that human drift motion is defined as the net displacement of the visual axis between flicks. In the cat, flick movements are extremely rare, thus making such a comparison difficult. Impulsive changes in the direction of visual axis have been observed when the cat is making gross voluntary eye movements.

We have recorded only the horizontal movements of the cat's eye carefully, but, from a very brief record of the vertical movements, it seems that these are of the same order in amplitude. In addition, some mention should be made of the gross voluntary torsional movements; these are very large compared with the human, and by inspection seem to exceed 30 degrees.

Ditchburn and Ginsborg (1953) have shown that the major eye movements (drifts, tremor, and flicks) are still present when a human subject's head is unrestrained but, in addition, the slow involuntary head rotations are partly compensated by rotations of the eye in its orbit. An attempt to photograph the cat's eye movements when the animal was free to move his head proved impossible, however, because of the gross movements of the cat.

Discussion

The major difference between the small eye movements of the human and those of the cat is that the cat makes flick movements on only rare occasions. The control and purpose of the flick movement is in doubt although Ditchburn and Ginsborg (1953) have suggested that they restore the image to the central fovea in humans, and Ditchburn (1956), Fender (1956), and Cornsweet (1956) have demonstrated their corrective nature. Unlike the human, the cat does not have a well-developed fovea, packed with cones alone. Instead, its central area has both kinds of receptors, and the density of concentration of these relative to the surrounding regions is not as great as it is in man (Chievitz, 1889; 1891). In addition, there is considerable anatomical overlap in the neural

pathways from the central area. It is to be presumed, therefore, that the acuity of the cat's eye does not fall off as steeply from the fixation point as does that of the human. If this assumption is made, we should expect that flick movements made during fixation would be less likely to occur in this animal.

In studying pattern vision or the effects of retinal stasis in acute preparations, the movements of the image across the retina which are produced by low frequency tremor should probably be duplicated since they have been shown to be important in restoring normal vision in experiments on retinal stasis in humans.

Ditchburn *et al.* (1959) showed that imposed motion similar to the natural flick and small amplitude tremor (less than 14c/sec.) restored normal vision while an imposed drift motion had little effect. Krauskopf (1957), using imposed tremor, found frequencies below 10 c/sec. to be most effective in restoring visual discrimination. Flicker frequencies below 10c/sec. were reported by Cornsweet (1956) to improve discrimination while Pritchard (1958) showed that the lower frequencies (of the order of 2c/sec.) were most effective in restoring visibility of the stabilized image. Apart from the adaptive, teleological significance, tremor is almost identical in cat and man. Physiologically, tremor may be inescapably due to imbalance of opposing muscles (Ditchburn & Ginsborg, 1953) holding for both species and also to be expected to exist in other species.

Summary

The eye movements of the cat during fixation were recorded by an optical lever method in conjunction with a continuously moving film strip. Three types of movement were observed: drifts, tremor, and flicks. The latter occur very rarely, compared with the human, possibly because of anatomical differences between the visual systems of cat and man. The data provided allow one to reproduce small eye movements when studying pattern vision in acute preparations, movements which have been shown to be essential for normal human visual function.

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BOOK REVIEWS

Statistical Analysis in Psychology and Education. By George A. Ferguson. New York: McGraw-Hill Book Co. 1960. Pp. viii, 347.

Professor Ferguson follows the classical pattern for basic texts in statistics. An introduction to basic terms and concepts is followed by an exposition of the descriptive uses of statistics, which is in turn followed by consideration of probability, sampling, and statistical inference. Such a book should have two main functions: first, to serve as an instruction manual, explaining why statistics are necessary, what their job is, the nature of statistical inference and other related concepts; secondly, to be a recipe book for the researcher, describing tests, how to use them, and the circumstances appropriate to their application. Since the book is intended for the non-mathematical reader, the first of these two functions can only be fulfilled in a limited sense, as Professor Ferguson notes in his Preface.

The first criticism to be offered is that, in the interests of fairly complete coverage of available tests and techniques, some of the explanatory passages have been kept brief, with possible loss of clarity for the novice. In this reviewer's experience, the explanation of statistical notions to non-mathematicians seems to require rather extensive use of examples and discussion of the steps in the arguments used. It is arguable, of course, that such explanation is better carried out in the classroom than in a textbook.

In the introductory chapter of the book we find an assortment of topics presented, including an excellent preliminary discussion of populations and samples, parameters and estimates—troublesome topics for most beginners. The next three chapters give a rather thorough treatment of frequency distributions, averages, measures of variation, skewness, and kurtosis. Free use is made of the summation notation, no doubt with good paedagogical intent. This is followed by chapters on probability and the normal curve, which might have been sugared with some examples designed to capture the student's interest. One has the uneasy feeling that too much talk of coin tossing may engender doubt as to the relevance of all this to experiments or problems the student himself is liable to encounter. Correlation, on the other hand, is treated in the next two chapters in immediate conjunction with practical problems of prediction, an excellent stratagem.

Chapters 9 and 10 contain the main treatment of the concepts on which the logic of statistical inference is based. One feels that the author's

attitude to his readers is somewhat uncompromising; the lack of informative examples, illustrative graphs, and so on makes this section fairly hard going. This is especially true when the null hypothesis, one-tailed and two-tailed tests, and sampling distributions are discussed. Here surely is the heart of the problem of teaching statistics, and treatment on a more extended basis would be in order. For instance, one doubts whether a student would have a very clear idea of when, and when not, to apply a one-tailed test after reading the relevant section. The arguments for one or the other type of test are not statistical, as Professor Ferguson emphasizes; they are, nevertheless, highly relevant to the statistical inference made, and a case for more detailed explanation could be made out on these grounds. The argument as presented is in fact very lucid, but to present an argument from unfamiliar premises in so compact a form is to ask a good deal of the student who has to follow it. The concepts of the power of a test, and of type I and type II errors, are not even mentioned although the former gets brief consideration later on.

The usual group of tests of significance is presented, followed by very adequate chapters on chi square, and rank correlation methods. The chapter on transformations, however, may seem disappointing, especially to experimental psychologists, for whom transformations are mainly of interest where non-normality and inequality of variance prevail. We are told (p. 212): "Where the departures from normality and equality of variance are gross, a transformation is sometimes used. Square-root and logarithmic transformations are appropriate to certain classes of data. A square-root transformation converts X to $\sqrt{X}$; a logarithmic transformation converts X to log X. Under the special circumstances where they are appropriate, these transformations may achieve approximate normality and equality of variance." This is not particularly helpful if we are not told what those circumstances are, nor where to find out. Their important application in the analysis of variance is scarcely mentioned (p. 240).

Analysis of variance is the topic of Chapters 15 and 16. Here again the presentation looks rather formidable, the table summarizing the formulae (p. 236) being particularly impressive. A much simpler presentation is possible, without loss of meaning, as for instance the table in Quenouille's *Introductory Statistics* (p. 55), which contains all that is needed to carry out a one-way analysis. Professor Ferguson's method of complete presentation of the general equations, before giving any illustrative example, mathematically elegant though it be, is not calculated to inspire confidence in the non-mathematician. The exposition of Edwards, for instance (*Statistical Methods for the Behavioral Sciences*), is surely much easier to follow. Professor Ferguson discusses the general statistical model

underlying the analysis of variance, and the work of Wilk and Kempthorne on expected mean squares, to arrive at a rational basis for the choice of error term in the analysis. This, and the description of methods for analyses involving unequal sub-classes, are admirable.

The chapter on non-parametric statistics is straightforward. The generally useful tables for the Mann-Whitney U-test are not included, and this seems an odd omission. The last two chapters are concerned with errors of measurement, and partial and multiple correlation. The former deals rather cursorily with the concept of true score, methods of estimating reliability, the Spearman-Brown formula, Kuder-Richardson formulae, and related topics, the latter with partial and multiple correlation and their uses. The usual set of tables is provided at the end of the book, a useful glossary of symbols, references, and an adequate index. No answers are given to the examples at the end of each chapter, nor is there a list of statistical formulae.

A number of criticisms of Professor Ferguson's book have been put forward, but they are mostly of a relatively minor order, and indicate a difference of opinion as to what should be emphasized in an introductory text rather than an assessment of the merits of the book as a whole. In this reviewer's opinion *Statistical Analysis in Psychology and Education* will be of most use to the abler student, or the one who already has some facility in mathematics, for whom it should be a very valuable introduction to the subject. Professor Ferguson's erudition, and his rather terse prose may make it slightly less assimilable for the less gifted than some other books of the same *genre*. In most other respects it is highly commendable; it achieves wide coverage within a fairly modest size, and it is beautifully set out and free from typographical errors.

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Speech and Brain Mechanisms. By Wilder Penfield and Lamar Roberts. Princeton: Princeton University Press, 1959. Pp. xiv, 286. $6.00.

Thought and Action. By Richard K. Overton. New York: Random House, 1959. Pp. 117. 95¢.

The problems of speech enter into every important branch of human psychology in one form or another. The acquisition of a language demands the ultimate in perceptual and motor learning; speech is intimately related to concept formation and thinking; verbal responses, once learned, are not forthcoming without motivation, and it is well known that words can be powerful arousers of motivation and emotion.

Whether we read or listen, we receive information in small fragments which must be stored long enough to be perceived as words and sentences. In speaking and writing the reverse process must be carried through; the complex movements must be executed in definite sequences for the purpose of communicating a single idea. Mental testing, clinical diagnoses, psychotherapy, and many other practical applications of psychology also depend to a great extent on language.

Penfield and Roberts do not overstate the case, therefore, when they say in the preface to *Speech and Brain Mechanisms*: "Psychologists may well find as much useful material in this monograph as the clinicians and neurophysiologists for whom it was originally intended." Much useful material is indeed to be found, but it is only fair to say that the search is more arduous than it need have been if the authors had devoted a little more care to the book's organization. Insufficient co-ordination between the contributions of the two authors accounts for some of the needless repetition that mars the work, and further redundancy results from the fact that part of the material retains too much of its original lecture form. (The book is based on the Vanuxem Lectures given at Princeton University in 1956 by Dr. Penfield.)

The first chapters review the general field of cortical localization, with emphasis on that revealed by electrical stimulation of conscious human patients. Unfortunately, unless he is of a forbearing nature, the psychologist is likely to be distracted from much that is interesting and useful by Penfield's digressions into the mind-body problem. Penfield is an interactionist in the tradition of Hippocrates and Descartes; he believes that the mind influences the brain and *vice versa*, not through the pineal gland, but through a group of medially located nuclei which he calls the centrencephalon. Fortunately for us, although taking for granted this division of labour between mind and brain, Penfield is as eager to push back the point at which the mind must be invoked to explain behaviour as are his more positivistic colleagues.

But if the philosophy is traditional, the neurology is not. Penfield and Roberts have had a unique opportunity to observe the effects of controlled brain dysfunction on speech in large numbers of patients, and they have not wasted the opportunity by conducting their studies in a hidebound way.

In a brief history of aphasia Roberts traces the rise and decline of the idea that highly specific deficits of language (nominal aphasia, alexia, etc.) exist in pure localizable forms. He then presents data which should finally put an end to the dogma that speech and handedness always go together, dependant on a general dominance of one cerebral hemisphere. Except in cases where the left hemisphere suffers damage during the first

two years of life, just as high a proportion of left-handed as right-handed patients become dysphasic after operations on the left hemisphere (about 73 per cent). Roberts also describes the sodium amytal test which allows the laterality of speech to be determined before operation by "knocking out" each half of the brain independently at different times. This technique should allow patients with bilateral representation of speech to be detected, but no conclusive evidence for such people has yet been found.

The rest of this section contains much that is new, or at variance with widely held beliefs; everyone who has to deal with abnormalities of speech, or indeed who wishes to be conversant with the latest data on brain function, should make himself familiar with these chapters.

The book proper concludes with a suggestion that the three cortical speech areas (Broca's in the frontal lobe, Wernicke's in the parieto-temporal region, and a recently discovered area lying in the longitudinal fissure) are linked together in the thalamus so that they operate as an integrated system. Included in the evidence for such an arrangement are a number of fibre dissections specially prepared by Dr. Klingler, photographs of which are presented. It goes without saying that this evidence strengthens the case for similar thalamocortical organization underlying other types of learned behaviour.

The book also contains an "epilogue" by Penfield on the desirability of teaching additional languages at an early age, his argument being based on neurophysiological data. Here, I fear, he falls into a trap usually reserved for physiological psychologists. It is debatable whether there is at present any purely physiological evidence that learning can take place at all, let alone that it is better at one time of life than another. The only evidence we have that children learn in a different way from adults is obtained by observing people learn. Nobody would challenge the behavioural observation that young children learn to *speak* (and to play instruments and games, motor skills of every variety) in a way which can rarely if ever be equalled later in life. But properly controlled research is needed to substantiate the claim that adults find it more difficult to acquire a working knowledge of a second language. However, it occurs to me that, if precocious polyglotism ever becomes widespread, children will evolve an interesting mixture for their own use and so hasten the advent of a universal language.

In summary, I should say that this book has a few faults but that they are far outweighed by the unique data and the wide ranging flow of ideas that it contains.

The style of Penfield and Roberts' book leaves one in no doubt that

it is addressed to educated adults, Overton's *Thought and Action* on the other hand is written in a way calculated to repel anybody in that category. Overton uses Hull-like postulates to develop a physiologically oriented cognitive behaviour theory somewhat similar to Hebb's. However he does not acknowledge his antecedents, apparently believing that the requirements of modesty are met by avoiding the use of the first person, and referring to himself as "the author."

Overton makes one important point more explicitly than Hebb does, that learning involves the selection of effective responses from a number of initially equally probable ones; but on the whole the treatment is superficial and he ignores, rather than dismisses, most of the stumbling blocks. Nevertheless, in spite of the book's misleading analogies, its over-simplified neurophysiology, and its nursery-book style, it may still find some use because it presents for the first time a really elementary version of current ideas in behaviour theory.

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Psychology and Human Performance: An Introduction to Psychology. By Robert M. Gagné and Edwin A. Fleishman. New York: Henry Holt and Company, 1959. Pp. xiv, 493. $7.25.

There are three general issues on which the merits of this book as an introductory text might be judged. The first two are related. The authors have attempted to provide the student with a systematic exposure to human performance characteristics. In doing so, they have, first, deliberately refrained from any systematic treatment of the *methods* which have evolved in experimental and applied human psychology to yield the data that they discuss; and second, they have also clearly avoided exposing the student to psychology as a *theoretical discipline*. No attempt has been made in the book to present theories as organizing or integrating devices, or to suggest the theoretical implications of human performance data. The authors make clear in their preface that they do not wish to emphasize any particular theoretical position. Apparently, for them, this entails the exclusion of all theories.

From the point of view of the teaching psychologist it is difficult to understand how these omissions could be held to be virtues in an introductory course. It is even more difficult to reconcile them with one of the authors' major purposes as enunciated in their preface: ". . . to impart the notion that the subject-matter of human behavior can appropriately

be viewed as science, and that the investigator uses the methods of science in obtaining these facts." For the student the result is a text without "reach," one that provides little stimulus or challenge; and that offers even less for the scholar in the class to wrestle with.

The third issue has to do with the content of the text. After the typical introductory chapter devoted to a discussion of psychology as a science, and its relations to biological, social, and physical sciences, the student is provided with a very thin introduction to human physiology and neurology. The next eight chapters treat the topics of memory, drives and motives, learning, sensory discrimination, perception of the physical environment, motor skills, concepts and thinking, and social behaviour. In the course of exploring these subjects (to mention some of the more apparent inadequacies) the brain and spinal cord are disposed of in six paragraphs, the distinction between the somatic and the autonomic nervous systems is left unmade, developmental psychology and psychology of personality are excluded, the topics of sensation and perception become discrimination and identification—which enables the authors to avoid the discussion of perceptual phenomena beyond the level of the perception of distance and size almost completely, and the subjects of individual differences and abnormal psychology receive no systematic treatment. However, this does enable the authors to bring us to the final four chapters of the text, which are devoted to job analysis, personnel selection methods, the evaluation of job proficiency, training methods, and human engineering. It becomes apparent that the chapters preceding these are intended to provide what the authors regard as a sufficient introduction to psychology to support the final chapters. These final chapters are inadequate compensation for the topics which were excluded in order to make room for them.

Throughout the book the emphasis is on what the human can do. Although a variety of illustrative material is used, the bulk of it pertains to characteristics of behaviour which are relevant to work performance. For example, of the more than one hundred graphs in the book, sixty or more illustrate sensory discrimination curves, learning curves, and production curves in training or work situations. One consequence of this and some of the other characteristics of the book that have been mentioned above is that the performing human fails to emerge as an integrated, complete organism.

To conclude: this book might provide an adequate basis for an only course in psychology to be taken as an elective subject by engineering and commerce undergraduates.

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Psychology in Theory and Practice. By THOMAS A. RINGNESS, HERBERT J. KLAUSMEIER and ARTHUR J. SINGER, JR. Boston: Houghton Mifflin Co., 1959. Pp. xii, 480. $6.00. *Contemporary Readings in General Psychology*. Edited by ROBERT S. DANIEL. Boston: Houghton Mifflin Co., 1959. Pp. xiv, 385. $3.25.

PSYCHOLOGY IN THEORY AND PRACTICE differs from most of the introductory texts in psychology. The three authors—two from the University of Wisconsin and one from Northern Illinois University—believe that "most important in a first course in psychology are the students themselves." It is for this reason apparently that the first hundred pages of the book deal with the general topic, Psychology and Student Life. These pages should prove of value not only to beginning students in psychology but to any freshman in any course. "Meeting the Challenge of College Life" and "Making the Most of Your Time and Ability" are the titles of the first two chapters in this section. The third and last chapter in Part One, entitled "Group Living," emphasizes the advantages of group membership and considers as well some of the problems of group living. This first part of the book is written, as the writers say, to "help college students get more from their college living and also to help them form a basis for more useful and happy lives in the future."

Psychology is defined in the glossary as "the scientific study of human behavior and experience." Psychology, we are told, is mainly concerned with the "mental workings of man". Nowhere do the authors offer an explicit definition of "mental workings" or of mind. It is quite evident, however, that they regard the subject-matter of psychology as including what some few of us obstinately still like to denote as conscious activities.

The topics in Part Two of the book are those commonly found in an introductory text in psychology. The chapters on Learning, Perception, and Thinking are especially well written. Part Three, again approximately one hundred pages, is really an introduction to social psychology. It includes as well an excellent short chapter on Mental Health. The last part of the book stresses some of the applications of psychology, and the final chapter considers the relation between psychology and philosophy. The authors certainly have written an unusual text in psychology. They have succeeded in presenting both theory and practice in psychology in an intellectually stimulating manner. There are relatively few typographical errors. Those that do appear, as on pages viii, 86, 152 (where six should surely read four), will doubtless be corrected in the next printing. The authors will want in future to refer to K. M. Banham-Bridges by the pronoun *she*, rather than the pronoun *he*, and Berkeley to whom passing reference is made on page 435 should not be called an

English philosopher. The book abounds in unusually fine graphic and pictorial illustration.

Daniel's *Contemporary Readings* is the result of a number of years of preparation and of testing with his own students. Those who use this well-organized compilation will perhaps be interested to discover that of the 68 selections 19 are from the *Scientific Monthly* and 12 from the *Scientific American*. The articles are in the main relatively easy reading, as probably they should be for beginning students. That does not mean, however, that they are not scientifically important. They are, and in this reviewer's opinion they provide the best selection of readings of this sort with which he is acquainted.

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Einführung in die Pharmakopsychologie. By Herbert Lippert. Bern and Stuttgart: Hans Huber. 1959. Pp. 254. Fr./DM 32.

Child Research in Psychopharmacology. By Seymour Fisher, Springfield, Ill.: Charles C. Thomas. 1959. Pp. xvi, 216.

Anyone interested in comparison of methods will find a model example provided by these two contrasting approaches to psychopharmacology. Lippert presents a collection of subjectively experienced phenomena categorized on the basis of Lersch's stratified personality theory and the aged faculty division of purposive dispositions, feeling, volition, imagery, expression, etc. A number of chemical formulae of the major psycho-active drugs are added in a separate chapter. The style is fluent and easy to understand. This is fortunate because it does not require the interested reader to struggle with terminological idiosyncrasies frequently encountered in phenomenological writings.

The need for a description of phenomenological consequences of drugs and for categorizing drugs according to psychological states, rather than chemical or physiological properties, can hardly be gainsaid. For this Lippert must receive credit. However, phenomenology and behavioural psychology, apart from differing in philosophy and the kind of phenomena recorded, are still deeply split on methods of observation. Although some experimental work on drug-induced changes of subjective experiences has been done no cognizance of this is taken by Lippert, nor does he attempt to systematize subjective phenomena as conditional on crucial factors such as dosage, single or mixed administration, age, personality, type and degree of abnormality, etc. The entire treatment is anecdotal and the necessity of experimental control is discouraged in favour of stressing the "art of experimentation."

A striking illustration of these shortcomings is provided by the loose bearing of the discussion on the literature. The index consists of 1,695 originally listed items, with 23 subsequent additions. Of the original items only 224, or 13.2 per cent, are listed in the text (while, strangely enough, almost all 23 added items are discussed). Less than ten frequently quoted authors provide by far most of the discussion material. Among these are Baudelaire, Gautier, W. James, and Heidegger, but hardly a modern experimenter of repute.

The American volume is based on papers and discussions by 22 paediatricians, psychologists, psychiatrists, and social workers. Characteristically, it is entitled psycho*pharmacology* rather than pharmaco-*psychology*. It begins with a pharmacological division of psycho-active drugs, concisely written by J. O. Cole and Carr. At least two of the more outstanding contributions, however, explicitly put the emphasis on much neglected psychology. Borstelmann believes that drugs should be used as experimental tools for behaviour study. Oddly enough, it fell to Lila Ghent, a physiological psychologist, to explicitly base her entire treatise on the use of chemical intervention as a means of investigation for psychological structure, or "interconnectedness" of functions. The practice of studying the effects of drugs on the original structure of psychological phenomena, which obviously derives from their medical use as agents for treatment, presumes invariance of such functions as learning, perception, motivation, etc. This conception may be very wrong and one should, instead, look for drug-induced behaviour groupings which cut across such functions or, in Lashley's terms, "factor out" drug-specific structures. This point of view, which was materially supported in a discussion by Elkes, may be of particular importance with regard to drive or motivational variables.

The general accent is on methodology rather than content. Ignoring conversational remarks on how and what to do and what to beware of, the reader will find some good systematic reports on methods and design (Borstelmann), measurement techniques (McCandless, Long) and regard for antecedent conditions emphasized in most contributions. They indicate that, after initial clinical enthusiasm has worn off, drug research with children as an area of objective, scientific enquiry is coming of age.

The research areas discussed may be grouped in four sections. First, the interaction of drugs with development is considered to a varying degree by all authors. Piaget's stages of cognition and Ego development are proposed by Eisenberg to provide a useful framework. Secondly, in contrast to the waning period of global assessment techniques, a number of contributors stress the lack of objectively defined, specific psychological functions and of factors of abnormality, against which drug effects may be

assessed. Thirdly, there is a growing and healthy concern for personality-specific reactions. Response inconsistencies, indicative of non-linear relationships, have been noted, but no concerted attempt at understanding or integration is made. Drug typology may well determine the effects of most other conditions and should, therefore, be treated as a basic research area. Fourthly, it was left to Sherman Ross to remind the gathering of the necessity of comparative drug research.

Considering the professional heterogeneity of contributors, more extensive evaluation of collaborative methods might have been expected. Apart from Clifford's interesting proposition of joint long-term developmental studies between NIMH and NINDB, an already existing collaborative study of neurological disorders, little tangible evidence is presented. An annotated reference list of 159 items, compiled by Bouthilet and Fisher, helps to round off a fair diversity of problems.

The volume is the result of a workshop discussion sponsored by the National Institute of Mental Health. The contributions were skilfully organized and edited by Seymour Fisher and should prove highly stimulating for both practice and research.

J. C. Brengelmann

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The Child in Hospital. By Hedley G. Dimock. Toronto: The Macmillan Company of Canada Limited, 1959. Pp. xvi, 236. $3.75.

This book is written on a non-technical level and perhaps is over-ambitious in scope as the author seeks to present an elementary treatment of child psychology, along with applications of child psychiatry, play therapy, group dynamics, non-directive counselling, staff planning and administration, and community leadership. Naturally, the treatment of any one of these important topics is somewhat less than profound. The author has, nevertheless, introduced many practical suggestions worthy of further study and has included a useful and comprehensive bibliography ranging in popular appeal from *the Ladies' Home Journal* to *The Psychoanalytic Study of the Child*. It is interesting to note that the earliest reference listed is 1938 and the majority come between 1947 and 1959. This in itself is indicative of the recency of concern over the problem indicated in the title, *The Child in Hospital*.

The book is in line with a significant trend highlighted in 1952 by the publication of the now well-known article by John Bowlby and his research associates, *A Two-Year-Old Goes to Hospital*, following the poignantly appealing and instructive film by the same name. This film

was part of a research project on the effects on child personality of separation from the mother in early childhood. Throughout the book under review, as well as the film, runs the theme of concern for the anxieties, fears, and insecurities which a child may experience through an encounter which involves not only pain and discomfort, but the additional threats of separation from parents and familiar scenes, and the introduction into the vast, shiny, stream-lined, efficient, antiseptic, and occasionally (though less often now thanks to the efforts of Dr. Bowlby, Dr. Dimock, and their psychological brethren) emotionally sterile atmosphere of the big hospital.

One of the most effective features of the book is the inclusion of a number of pertinent case studies. The author presents in clear-cut fashion the contrast between the reactions of children well and badly prepared for hospitalization and points out that "there is some evidence that the emotionally and socially happy children get well faster and go home sooner." Dr. Dimock presents ample documentation of childhood experiences leading to fear of doctors and consequently of hospitals, and quotes a research study showing that doctors are feared most next to dogs among pre-schoolers (page 42). But that was in the thirties and we hope and believe that doctors have improved somewhat on their child-*rapport* techniques since then.

The author deals sympathetically with the problems of the child caught in an emotional triangle with the mother and the nurse. "The nurse-parent relationship is packed with emotional dynamite on both sides. Just a little friction is needed to set off the fireworks." Insight and understanding on both sides are essential to avoid the conflagration.

The pithy accounts of actual activities of children in hospital are in pleasant contrast to some of the rather trite and repetitious theorizing. For an example of the latter, consider this paragraph regarding the importance of inter-personal relations: "A staff member has relations with any other staff member with whom he has communication, even if just by telephone or memorandum. The sum of all the individual inter-personal relations equals the inter-personal relations of the hospital staff." Koffka, Köhler, and company convinced us fairly thoroughly some years ago that this kind of mental arithmetic doesn't "add up", and even if they hadn't we would feel tempted to inquire, "So what?"

Among suggestions for play activities for the child in hospital the author mentions that "the urge of small children for free and uninterrupted experimentation with water has growth potentialities which seem to have been almost completely overlooked." It is obvious that this suggestion might not be fully adaptable to the hospital situation and might meet with considerable resistance from the nursing staff, but it

seems definitely worthy of further investigation and certainly there could be no objection to the compromise suggestion of making more use of bath time for enjoyment of this form of play.

In conclusion, the carefully prepared bibliography, the practical suggestions, and the interesting lines of investigation opened up regarding inter-personal relations in the hospital make this book well worth its comparatively modest price.

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